GSWA Lower Lesueur 2D Seismic Survey

A summary on the impact of the new seismic survey on the South West Hub Carbon Capture and Storage Project
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1 Introduction

1.1 Seismic Survey

The earth is composed of multiple layers of rock deposited over millions of years. Some of these layers trap resources (water, minerals, oil, and gas) and also hold potential for storing large volumes of CO₂ for thousands of years. Geoscientists use a number of techniques to map these layers and subsequently develop models for what the earth at that location may look like in cross-section. A seismic survey is one such technique and is used widely in the mineral and oil and gas industry.

A seismic survey records sound waves reflected by rock layers (geological formations). These sound waves are used to image the different layers of rock below the surface. It can be compared to an ultrasound test that doctors perform in a human body but at different scale and frequency.

The survey is conducted by installing receivers or sensors called geophones at the surface to record the echoes that were reflected by the rock layers below the surface. To create the echoes or waves, sound sources such as special vibration trucks are used. These trucks are equipped with large pads that send vibrations through the earth.

In conducting a seismic survey, the crew will place a series of cables equipped with geophones along a grid over the area to be mapped. Once geophones are placed, vibration trucks will move in tandem down pre-defined paths lowering a vibration pad onto the earth’s surface every few meters. The waves created by the pad will travel deep underground and be reflected back as echoes from different rock layers. These reflections are picked up by the geophones and sent to a recording system, which captures the data for computer processing and analysis.

From the timing of the reflection data, the depths of the layers can be determined, and an image of the subsurface can be formed.

![Image](image1.png)

Figure 1-1: Images above show how the sound waves transmitted by the vibration trucks bounce off each layer of rock and are collected by the geophones and transmitted to the recording truck. As sound waves travel deeper they continue to bounce each rock layer.

1.2 The South-West Hub Project Exploration Program

Under this program the suitability of Lower Lesueur area as a site for storing CO₂ underground for the South West Hub Carbon Capture and Storage Project is being assessed. This exploration program will help improve the understanding of the Lower Lesueur area with regards to its potential for storing large volumes of industrial CO₂ underground safely.

Seismic data of various vintages from the 60’s to 2008 was available for the initial studies conducted in the South West region, however the majority of the data was old and of poor quality. As the South-West Hub Project
developed there was need for more data to help better define the geology. As part of the exploration program, new seismic data was acquired in March 2011 by Geological Survey WA (GSWA); hereafter referred to as Lower Lesueur seismic. In addition, a new stratigraphic well; the proposed Harvey-1 well is scheduled to be drilled in January 2012.

The Lower Lesueur seismic was interpreted and incorporated into the existing geological interpretation and used to assist in the design of Harvey-1 well. Figure 1-2 shows the location of the study area and the well and seismic that was used to assist the interpretation.

This initial stage of the exploration program will guide a subsequent stage wherein more seismic data will be acquired over a broader region and more wells drilled. This process will allow a staged development building technical confidence in the storage site.

Figure 1-2: Location map showing offset wells and existing seismic in white, proposed GSWA Harvey-1 in blue and Lower Lesueur seismic in red. The study area is within the yellow box.
2 Lower Lesueur Seismic

2.1 Horizon and Fault Interpretations

In order to evaluate the geological formations (reservoirs) that have the potential for storing CO₂, existing seismic together with the new Lower Lesueur seismic needed to be interpreted. Horizon (layer tops) interpretation of seismic reflectors identifies the different reservoirs while fault interpretation defines the storage container boundaries. Three main seismic reflectors were selected for interpretation due to their continuity through most of the study area. They are the unconformity, top Wonnerup and base Lesueur reflectors and can be correlated to geological formations by stratigraphic table (see Figure 2-1). In the study area, the Lesueur Sandstone which can be divided to two members; Myalup and Wonnerup, has been identified as having potential for storing CO₂.

![Stratigraphic Table](image)

Figure 2-1: Stratigraphic column of the southern Perth Basin showing the interpreted horizons and proposed reservoir intervals (the Myalup and Wonnerup Members of the Lesueur Sandstone).

In the older seismic surveys the data quality is poor without good continuous reflectors (see Figure 2-2). In the newer Lower Lesueur seismic, it is easy to identify the top and bottom layers straddling the distinctive transparent zone (see Figure 2-3).
Figure 2-2: The seismic panel above from the Preston Detail seismic (acquired in 1970) has an east-west orientation. There is no clear seismic character (reflectors) and the image is chaotic. Reservoirs of interest, thus the location for injecting CO\textsubscript{2}, is hard to identify.

Figure 2-3: The panel above is from the new Lower Lesueur seismic and has similar east-west orientation as the one in Figure 2-2. There is a major improvement in the seismic character and the new data allows the reservoirs to be imaged clearly.
The study area is confined to the east by the Darling Fault and dominated by three fault trends (N, NW and NE striking faults) which are related to the orientation of geological rifting events after these formations were deposited millions of years ago. Many more faults can now be interpreted towards the eastern side of the area of interest due to the new Lesueur Seismic (see Figure 2-4). As can be seen from the new data the area is more compartmentalised than previously assumed. This is very important information and has an impact on determining the container size and the volume of CO$_2$ that can be safely stored.

Figure 2-4: Both seismic panels have similar east-west orientation. The seismic panel at the top has limited faults interpreted due to lack of clear reflectors (poor data quality) and the interpretation could not be extended to the east due to lack of seismic coverage. However, the seismic panel at the bottom has more faults interpreted and the interpretation extends further east due to the extension the seismic coverage from the new Lower Lesueur seismic.
2.2 Conclusion
The new Lower Lesueur seismic is of better quality data than older seismic surveys. This allows

1) Better delineation of the target reservoirs and improved definition of storage capacity.
2) Appropriate selection of the Harvey-1 well location. The proposed well location avoids any interpreted faults, and the definition of the structure around the well is clearer. This can be seen when comparing the old and the new maps (Figure 2-5). Compared to earlier interpretations, the area of interest is more faulted and therefore compartmentalised. This may have an impact on the amount of CO₂ that can be injected (Figure 2-5).

![Figure 2-5](image)

Figure 2-5: On the left is the updated map for top Wonnerup based on new data from Lower Lesueur seismic. On the right was the older interpretation form phase 1(b) work. Note how the area of interest is now more compartmentalised.

3 Next Steps
Result from the drilling of proposed Harvey-1 well combined with the current reservoir and containment definition from Lower Lesueur seismic will assist in defining the next data acquisition stage of the exploration program wherein more focused seismic and wells can be planned. The integration of all this data will allow taking informed steps towards building technical confidence in the South West Hub Carbon Capture and Storage Project.
4. Planning the Research

4.1 Well purpose

Based on the seismic interpretation and the identified well location, DMP determined that well purpose was to reduce the geological data gaps in the area. The objectives of the stratigraphic well are:

- To confirm the prognosed stratigraphy is present.
- To evaluate the sealing capacity of the lower Eneabba Formation and confirm the presence of a lower shale unit.
- To collect fresh core samples of both the Eneabba Formation and Lesueur Sandstone for seal capacity of the former and reservoir characterisation and injectivity for CO\textsubscript{2} of the latter.
- To obtain a better time-depth relationship (checkshot/vsp) in order to tie well to seismic data.
- To update the current 3D geological model based on site specific information.
- To assist in the planning and development of future boreholes and seismic programs for evaluating the CO\textsubscript{2} storage potential of the area.
- To run modern evaluation logs, take possible sidewall core (SWC) and obtain modular formation dynamic tester (MDT) suites and thus develop a good understanding of the reservoir properties as well as the potential sealing unit in the vicinity of the well.
- To assess the hydraulic relationships within the heterogeneous Eneabba Formation (this is to find out if the unconventional seal has the capacity to contain the CO\textsubscript{2}).
- To assess the geothermal and hydrocarbon potential.

4.2 Drilling Data Acquisition Program

Under the works cope, no in-situ well testing of CO\textsubscript{2} injection was planned. SCS, in conjunction with DMP put together a detailed well proposal. Central to this was the “Drilling Data Acquisition Program" which identified the following:

- Mudlogging;
- Drill cuttings;
- Coring (approximately 300 metres over 4 different intervals);
- Wireline conveyed testing;
- Fluid sampling; and
- Laboratory testing.

4.3 Research Workshop

DMP and ANLEC R&D, in conjunction with SCS, analysed the work to be undertaken as a part of the drilling rig program and determined what could be done by the expertise available within DMP, what could be undertake by commercial laboratories and service providers and what the research components were required. A paper was developed and forwarded to the South West Hub principal research partners in the Western Australian Energy Research Alliance (WA:ERA – comprising the CSIRO, the University of Western Australia and Curtin University) for a research workshop in October 2011. In addition, representatives of the drilling supervisors, private sector, Department of Resources Energy and Tourism and other State and interstate agencies were invited.
4.4 Targeted Research

Five key research areas were identified and detailed research specifications were developed. This research will be undertaken by Agreement between ANLEC R&D and the Department of Mines and Petroleum with ANLEC R&D to be responsible for contract arrangements with the researchers. DMP will supply the core, core data and well data to the different research projects.

4.4.1 Stratigraphic Forward Modelling for the Lesueur: South West Hub

The SWCH Demonstration will use conventional techniques to assess its storage reservoir characteristics. There is a unique opportunity to supplement these with a suite of new methods, strategies and protocols that may enable lower cost, faster turnaround and improved data quality. The research objective is to test and validate the use of such innovative techniques. The ANLEC project Stratigraphic Forward Modelling for the Lesueur will produce an alternative version of the static model with inter-well variation based on a physics based algorithm that predicts grain-size distribution.

4.4.2 Facies-based rock properties distribution along the Harvey 1 stratigraphic well

This research project is designed to provide timely high-end analysis of core, not available through commercial laboratories, to support stage gate decisions on SW Hub 3D Seismic acquisition and processing workflow, and site selection of the pilot injection. These results will also have follow on application to further understand the geological and geophysical parameters that will affect the safe and efficient storage of CO₂ more generally.

The project proposes to incorporate GSWA and commercial laboratory analytical results into a combination of geological, petrophysical and rock physical core investigations which will provide a high end laboratory calibration of wireline log analysis acquired at the stratigraphic Harvey-1 well.

4.4.3 Geochemical characterisation of gases, fluids and rocks in the Harvey-1 data well

Research Objective

This proposal is aimed at obtaining timely and accurate data of a geochemical nature from the Harvey-1 data well. The data are required as input for improving the understanding of the geology in the target region for the SW CO₂ Hub Flagship project. The Harvey-1 well is the first data collection of a systematic investigation to evaluate the viability of the region for safe and secure carbon storage. A staged approach to collecting information and developing an understanding of the geochemical regime in the area is a vital scientific contribution towards building the case for a commercial CCS demonstration at the South West CO₂ Hub, by researching various geochemical aspects of the system complimentary to industry standard characterisation, risks and uncertainties on the predicted behaviour of the system will be reduced. The information will be applied to the static and dynamic models for the area to better characterise the storage capacity, containment security and injectivity of the site and move it closer to commercial CCS implementation.
4.4.4  Integration of Data from Harvey-1 well to support decisions – Fault Seal

The available seismic data for the Collie Hub clearly indicates that multiscale faults affect the target CO₂ storage reservoir of Lesueur Formations and the potential top seal Eneabba Formation. Based on the integration of existing and new (2010 vintage) 2D seismic dataset and Harvey-1 well data, this project primarily targets the evaluation of the faults hydraulic behavior, i.e. the faults sealing potential for across-fault and up-fault flows. A secondary objective is to investigate the distribution of sub-seismic fractures and their impact on the trap integrity and reservoir compartmentalization.

4.4.5  Advanced Geophysical data analysis for the South West Hub Harvey-1 well site

The outcomes of the geophysical data analysis will be used to assist further development of the South West Hub project, including designing the 3D seismic acquisition and processing program, updating the storage site 3D geological model and targeting positions of the next set of wells. Results include geophysical data analysis that will assist with assessment of the storage site key parameters: reservoir storage capacity, injectivity, sealing potential and long term site stability (stress, seismicity, and seal).

Harvey 1 well at sunset.  
Photo courtesy of Mark Mitchell, Aztech Well Construction
4 References


www.dmp.wa.gov.au

www.anlecrd.com.au