# In-Situ Laboratory for $CO_2$ controlled-release experiments and monitoring in a fault zone in Western Australia

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## SUMMARY

The In-Situ Laboratory Project (In-situ Lab) entails a configuration of wells at approximately 400 m depth for monitoring the controlled release of $CO_2$ in a fault zone at the South West Hub CCS Flagship project in Western Australia. The project aims to evaluate the ability to monitor and detect unwanted leakage of $CO_2$ from a storage complex. The In-Situ Lab consists of three instrumented wells up to 400 m deep: 1) Harvey-2 – primarily for $CO_2$ injection, 2) a fiberglass geophysical monitoring well with behind-casing instrumentation, and 3) a shallow groundwater well for fluid sampling.
A controlled- release test involving the injection of 38 tonnes of $CO_2$ between 336-342 m depth was conducted successfully in February 2019. Monitoring during the $CO_2$ controlled-release test included: a) continuous downhole pressure and temperature recording in the injection well, b) recording of pressure and temperature at the wellhead and at various points in the injection system, c) regular distributed temperature measurements, d) multiple vertical seismic profiling surveys using the behind-casing distributed acoustic sensor fiber-optic cable and geophones, e) electric resistivity imaging, f) groundwater sampling, g) comprehensive soil flux and atmospheric monitoring surveys, h) collection of gas samples from the surface injection facilities, i) recording of passive seismic data close to the injection well and in the wider area around the well lease, j) downhole video camera surveys, and k) pulsed neutron and induction logging.
The In-Situ Lab has the potential to form an enduring research facility at the South West Hub to enable further research of the characterisation of $CO_2$ migration in fault zones and the shallow groundwater environment.

**Key words:** $CO_2$ controlled-release, Western Australia, $CO_2$ geological storage, fault zone, $CO_2$ monitoring

## INTRODUCTION

The In-Situ Laboratory Project (Michael et al., 2019), entails a configuration of wells at approximately 400 m depth for monitoring the release of a small volume of $CO_2$ for testing purposes in a fault zone (Figure 1) at the South West Hub CCS Flagship project (SW Hub) in Western Australia. The SW Hub is a 'greenfield' investigation site south of Perth, which had little pre-existing subsurface data available to perform geological site characterisation (Sharma et al., 2014). Thus acquiring geoscience data for the site has been a focused effort during the past seven years.

The storage concept of the SW Hub involves injection of $CO_2$ in the deeper portions of the Wonnerup Member of the Middle to Late Triassic Lesueur Sandstone Formation, where it will be contained largely due to residual trapping and dissolution of $CO_2$ in formation water (Sharma and Van Gent, 2019). The Wonnerup Member is a relatively homogeneous reservoir unit up to 1000 m thick and dominated by sandstones. The sediments of the overlying Yalgorup Member are characteristic of a meandering fluvial environment, dominated by point bars with splays and occasional muddy abandonment and lacustrine units. Paleosols are extensively developed where the tops of units remained exposed and form low-permeability baffles. These sediments continue in the overlying Jurassic Eneabba Formation. The Eneabba Formation is truncated by the major Valanginian Unconformity and overlain by the Lower Cretaceous Leederville Formation, the latter consisting of contiguous layers of clay aquitards and sandstone aquifers.

The Harvey-2 well, previously drilled by the Western Australian Department of Mines, Industry Regulation and Safety (DMIRS) at the boundary of the investigated area, intersects a major fault zone with a maximum throw up to 1,000 m. Harvey-2 was initially drilled to a depth of approximately 1350 m, but was plugged back with cement to 400 m depth at the level of the Eneabba Formation due to wellbore stability issues. The depth and location provided an opportunity to establish a complementary monitoring well at a distance of 6 m from the original well (Figure 1) to conduct a $CO_2$ controlled-release test at greater depth than others conducted in Australia to date. The purpose of the In-Situ Lab is to leverage the availability of the Harvey-2 well and to evaluate the ability to monitor and detect unwanted leakage of $CO_2$ from a storage complex, which will contribute to broadening the global portfolio of controlled $CO_2$ release tests. Additionally, this project will produce a legacy site for

domestic and international training, capacity development, and technology testing.

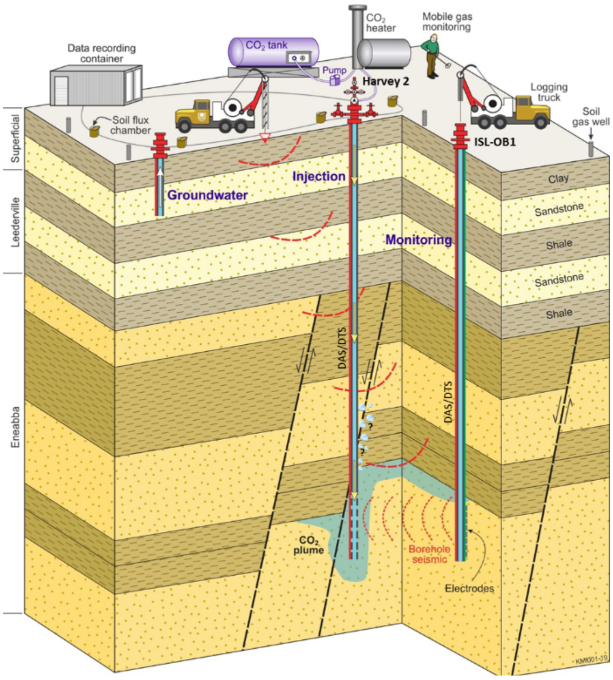


**Figure 1. Schematic of the In-Situ Lab well configuration, experimental set up and monitoring activities (not to scale). The injection and monitoring wells are approximately 400 m deep.**

## METHOD AND RESULTS

The field site for $CO_2$ injection testing was prepared between October 2018 and January2019 and included:

1. Drilling, completion and instrumentation of the new geophysical monitoring well ISL-OB1;
2. Perforating and completion of Harvey-2 as the $CO_2$ injection well;
3. Deployment of surface facilities ($CO_2$ pump and $CO_2$ heater);
4. Baseline monitoring (atmospheric, soil flux and groundwater sampling).

In February 2019, 38 tonnes of food-grade $CO_2$ (gaseous) were injected over 5 days through the Harvey-2 well. Injection occurred between 336 – 342 m depth into a sandstone interval capped by a paleosol unit. The injection rate varied between 0.1 - 1.1 tonnes/hour, generally increasing with time.

Towards the end of the controlled- release experiment, an unexpected leak occurred in ISL-OB1 due to damage of the fiberglass casing at 336 m depth. As a result, a mixture of less than 1 ton of $CO_2$ and up to 20,000 litres of formation water with a salinity of 25 g/l was released at the surface. The spill was constrained to the well pad area and had negligible environmental impacts. The well was subsequently cemented across the leakage point and $CO_2$ resistant cement was deployed above a permanent plug at approximately 280 m depth. The behind-casing instrumentation has not been affected by the leakage incident and the well continuous to be accessible for logging to the plugged back depth.

Monitoring during the controlled release of $CO_2$ included: a) continuous downhole pressure and temperature recording in the injection well, b) recording of pressure and temperature at the wellhead and at various points in the injection system, c) regular distributed temperature measurements (DTS), d) multiple vertical seismic profiling surveys using the behind-casing distributed acoustic sensor (DAS) fiber-optic cable and geophones (Tertyshnikov et al., 2019), e) electric resistivity imaging (ERI) (Harris et al., 2019), f) groundwater sampling, g) comprehensive soil flux and atmospheric monitoring surveys, h) collection of gas samples from the surface injection facilities, i) recording of passive seismic data close to the injection well and in the wider area around the well lease, j) downhole video camera surveys, k) pulsed neutron and induction logging.

The preliminary results can be summarised as follows:

1. Injectivity was lower than predicted from core measurements and modelling; possibly due to a combination of wellbore damage, mud invasion and reservoir compartmentalisation.
2. The injected $CO_2$ reached the ISL-OB1 monitoring well after approximately 4 days and an injection volume of 30 tonnes. Arrival was detected by DTS and ERI, and the plume was visualised by borehole seismic.
3. No vertical $CO_2$ migration has been detected beyond the injection interval; no notable changes were observed in groundwater quality or soil gas chemistry (up to two months after injection has stopped).
4. The dynamics of $CO_2$ and formation water leakage through ISL-OB1 were recorded with DAS and DTS.

Downhole and environmental post-injection monitoring is ongoing and the project team is currently planning future experiments at the site.

## CONCLUSIONS

Thirty-eight tonnes of food-grade $CO_2$ were injected and monitored in a controlled-release experiment at the In-Situ Lab project in Western Australia. The intermediate depth of injection (332-342 m) sets this project apart from shallow-release tests (<25 m) and actual $CO_2$ storage experiments (>1000 m) and thereby provides new insights into the monitorability of potential $CO_2$ leakage before it reaches shallow groundwater or the atmosphere. It is also one of the first injection experiments into a fault zone.

Behind-casing instrumentation in the designated monitoring well, particularly fiberoptics (DTS & DAS), provided promising results with respect to continuous monitoring of subsurface temperature, and the reliable detection of the $CO_2$ plume. No $CO_2$ leakage to groundwater or the atmosphere has been observed up to two months after the injection test. Further analysis, modelling and interpretation of the obtained test data are currently being conducted. Results from these undertakings in conjunction with ongoing post-injection monitoring activities will lead to a better understanding of the effects of fault geometry on $CO_2$ plume migration and for planning of future injection experiments.

## ACKNOWLEDGEMENTS

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