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Expanding a sparse seismic monitoring array at the Newell County Field Research Station

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Summary

Carbon Management Canada and our partners have expanded the sparse monitoring array at our Geological CO2 Storage (GCS) Field Research Station (FRS) in Newell County, Alberta, to test a sparse multi-physics nodal approach to GCS monitoring. The installation and operation of automated seismic sources and electromagnetic antennae at the FRS have provided practical insights into the costs and effectiveness of sparse monitoring. New installations include permanent vibrational seismic sources on various steel piles and on a reinforced concrete pad. An older steel pile on-site had previously been shown to transmit seismic signals with high fidelity. Newly installed piles displayed more obvious resonance effects, dependent both on pile length and mass of affixed equipment. A de-signaturing step with recordings from geophones below the pile toes successfully mitigated those effects. These pilot traces are integrated into an automated workflow for repeat vertical seismic profile monitoring with the goal of adding automated common midpoint reflection analysis between nodes.

Method

At the Field Research Station (FRS) in Newell Country, Alberta, Carbon Management Canada (CMC) has been simulating a CO_2 storage leak by injecting a small volume of CO_2 at ~300m depth into the Basal Belly River Sandstone formation (Macquet et al., 2022). Recently, CMC has established a sparse active-source seismic monitoring system at the FRS to test new, cost-effective technologies for monitoring CO_2 plume migration (Nyffenegger et al., 2025). Building around pre-existing monitoring infrastructure on site, the array has developed into three permanent source points (SP) with co-located geophones, located at 'optimum offset' (Hunter and Pullan, 1989) within 100 m – 200 m from each other and from a variety of permanent seismic sensors. Figure 1 shows the layout of the SPs and sensors most proximal to the injection well and observation wells (themselves containing distributed acoustic sensing fibre and geophones), including a SADAR® array operated by Geospace Technologies (Zhang et al., 2023) and an experimental fibre array operated by the CREWES consortium at the University of Calgary (Hall et al., 2025). A variety of other sensor types exist beyond the area depicted in Figure 1A. Figure 1B shows a section view schematic of the three SPs, depicting the steel pile depths and geophones installed both within and outside of the steel piles. The steel piles host MV4k and MV11k surface linear vibrator (SLV) sources from GPUSA Inc. and a prototype seismic source developed by Hyfold Technologies Corp. A reinforced concrete block was installed at SP3, hosting two surface orbital vibrator motors (SOV) from Class VI Solutions Inc.

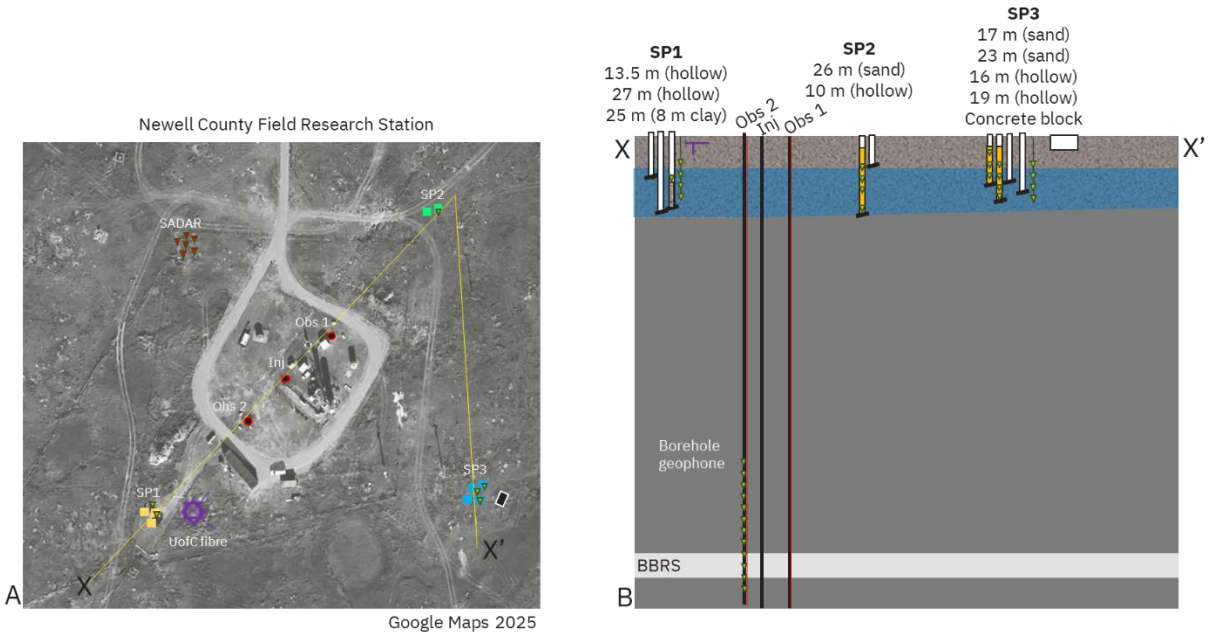


Figure 1. A) Layout of a selection of sparse monitoring installations at the FRS, excluding strain and EM hardware. B) Schematic cross section X-X' showing the various pile installations at three sparse nodes including geophones within and outside the piles depicted as green triangles.

An important component of this deployment is the use of 10 m – 26 m deep steel helical piles as waveguides for stationary active seismic sources. The piles transmit seismic signals through the steel, bypassing the dispersive unconsolidated shallow sediment layer. The intention of the steel piles (and concrete block) in the sparse array was to provide repeatable, high-fidelity transmission of highly-repeatable permanent automated sources. We experimented with installing 3-C geophones inside and outside the piles, with both sand and cement used to couple the geophones to the piles. Additionally, 3-C geophones have been installed at SP1 and SP3 locations by grouting them in at depths of approximately 10 m – 25 m. The purpose of the different geophone installations was threefold: 1) Evaluate the signal transmission within the pile, 2) Record a pilot trace to de-signature the source signal from other sparse receivers, and 3) provide redundant midpoint reflections between each SP for monitoring purposes.

A series of sledgehammer tests were performed in late 2025 to evaluate the signal transmission and transfer function properties of the piles when installed with different depths (lengths of pipe) and under different static loads. Three geophones installed at the base (toe) of three piles transmit data in near-real time, allowing for an automated workflow to be developed to de-signature the source signals from other real-time recordings such as borehole geophones in Observation Well #2.

Observations and Conclusions

In prior tests, resonance in the original steel pile on-site appeared to be damped by the confining sediment. Sledgehammer tests on piles installed in 2025 showed stronger resonance.

Immediately after installation, the signal transmitted from a 27 m deep pile at SP1 showed a doublet first-arrival, rather than a sharp impulse, followed by resonant tail (Figure 2A). Over three days, the confining sediment appeared to tighten up around the pile, and the hammer strike signal became sharper and more impulsive, a process which took seven days for a neighbouring pile installed at half the depth. The 27 m pile maintained a pronounced resonance (Figure 2B) even after the presumed tightening of the confining sediment. The piles are capped with steel plates of various designs intended to host different sources. To simulate the weight of a small seismic source, we bolted on approximately 50 kg of additional steel plating and piled on approximately 30 kg of sand bags to the 27 m deep pile at SP1. The additional mass decreased the resonant frequency (Figure 2C), a result consistent with the behaviour of a weight on one end of a massive spring.

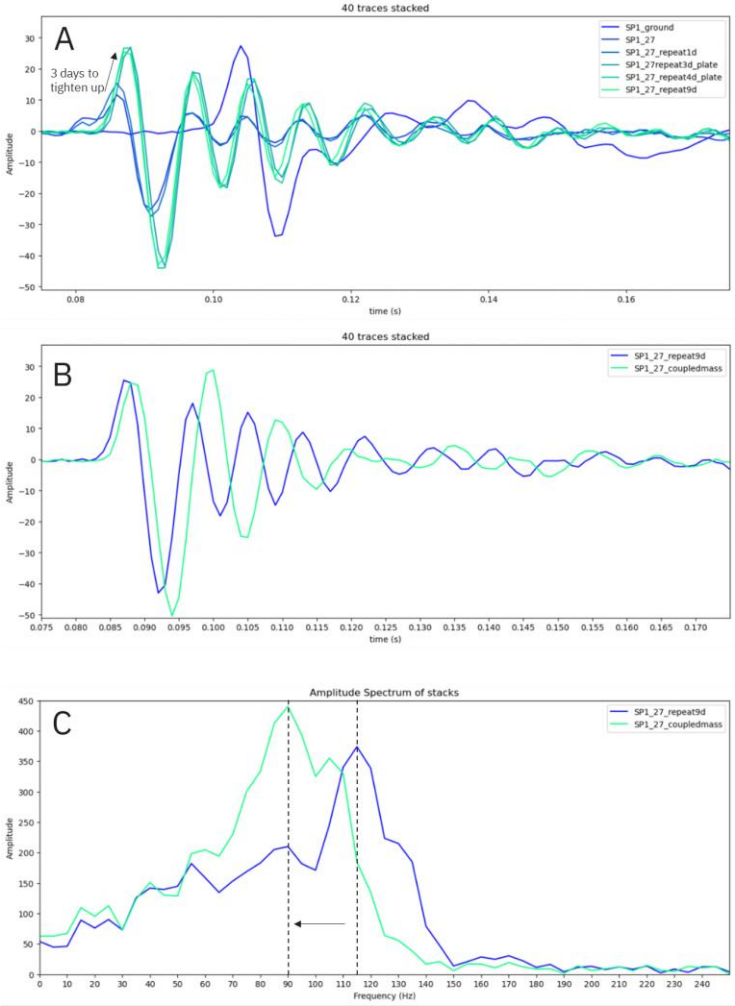


Figure 2. Hammer strikes on 25 m and 27 m deep adjacent piles, showing A) improved coupling three days after installation, B) Resonance and damping effects in a 27 m pile before and after coupling an 80 kg mass and C) decrease in the resonant frequency with the coupled mass.

By using the pilot trace recordings from geophones below the steel piles, much of the resonance and other transfer function effects from the piles could be mitigated by a de-signaturing

(deconvolution) process. Piles grouped at each SP location exhibited similar behaviour as their immediate neighbours in terms of signal amplitude and resonance, but different behaviour from the groups of piles at other SPs. This indicates a localized difference in the sediment coupling and the elastic behaviour and damping of the piles at each location. When comparing hammer strikes to vibrational sources, which add both static and dynamic load to the piles, broad similarities exist in the amplitude spectra following the de-signaturing step in terms of bandwidth, but within the recorded bandwidth differences in amplitude persisted at certain frequencies. This indicates that the steel pile coupled to both the massive source and to the confining sediment, acts as a more complex system than a simple waveguide bypassing the effects of the confining sediment.

Novel/Additive Information

This work provides insights into operating permanent seismic source deployments for sparse, automated CO_2 monitoring networks.

Acknowledgements

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