

Moving Towards Gigaton Scale CO₂ Storage in the Wabamun Area, Alberta, Canada

Chris L. Eisinger^{1*}, Rob Lavoie¹, Seyyed Ghaderi¹, Bernhard Mayer², Jerry L. Jensen^{2,3}, Don Lawton², Somayeh Goodarzi³, David Keith^{1,3}

¹ Energy & Environmental Systems Group, University of Calgary, 2500 University Drive NW, Calgary, AB, Canada T2N 1N4

² Department of Geoscience, University of Calgary, 2500 University Drive NW, Calgary, AB, Canada T2N 1N4

³ Department of Chemical and Petroleum Engineering, University of Calgary, 2500 University Drive NW, Calgary, AB, Canada T2N 1N4

Introduction

The Wabamun Area Sequestration Project (WASP) is a major integrated, multidisciplinary study investigating the potential for large-scale CO₂ sequestration (>20 Mt/yr) in a deep saline aquifer in the Wabamun Lake area, southwest of Edmonton, Alberta, Canada (Fig. 1). Four large coal-fired power plants in the region produce on the order of 30 Mt CO₂/yr, with the goal being to inject 1 Gt of these emissions over 50 years. TransAlta, one of the industry sponsors for WASP, was recently awarded federal and provincial funding for the Pioneer Project. Located within the WASP boundary, this commercially driven project aims to inject 1 MT/yr CO₂ from the Keephills 3 power plant beginning in 2013.

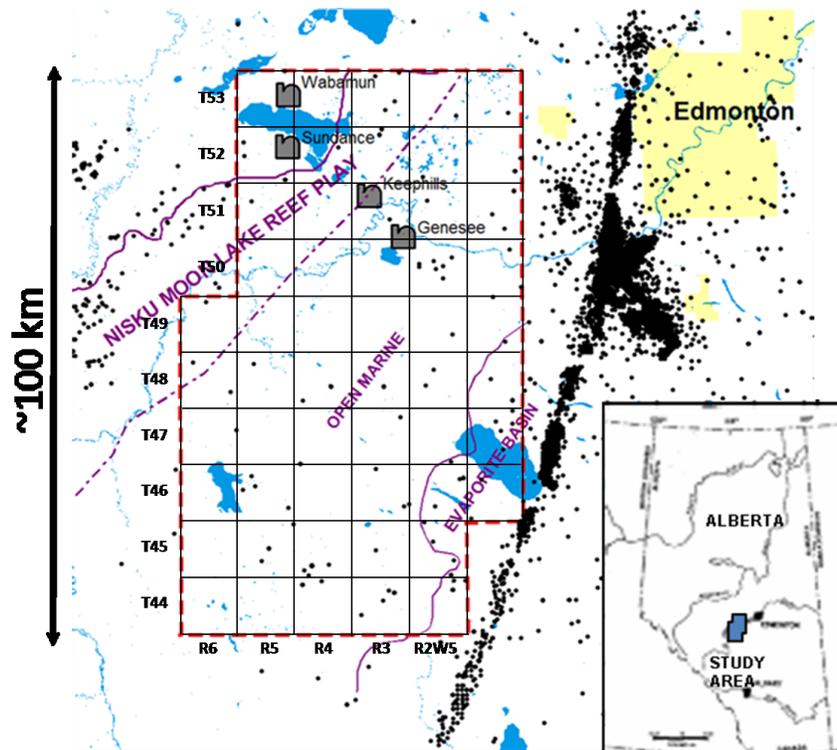


Figure 1: WASP study area (red outline, ~5000 km²) and locations of four power plants. Black circles indicate wells that penetrate Nisku Fm.; purple lines delineate depositional boundaries for carbonate platform in Upper Devonian.

WASP Phase I

The first phase of WASP focused on establishing the viability of the Devonian Nisku Formation carbonate for injection. Key outcomes include:

- 1) The injection potential was estimated to be on the order of 0.2 to 0.3 Gt for 50 years using conventional drilling methods, and 0.4 to 0.5 Gt using horizontal drilling and hydrofracturing methods (Fig. 2). The median permeability is estimated to be 30 mD or less which inhibits potential flow capacity in the formation. Aquifer connectivity for the study area is also not well known. These storage capacity estimates represent a lower boundary assuming no active reservoir management.



Figure 2: Nisku Fm. injectivity using various well orientations and drilling technologies. V - vertical; H - horizontal; HF - hydrofracturing.

- 2) The presence of dissolved H_2S in the aquifer brine was recognized and potential complications and risks during CO_2 injection were assessed. Compositional modeling (Fig. 3) shows that the mole fraction of H_2S in the gas phase can exceed the mole fraction of CO_2 at the front of the expanding CO_2 plume. This warrants attention for monitoring of potential leaks, although the risk will be reduced as the front is not static.

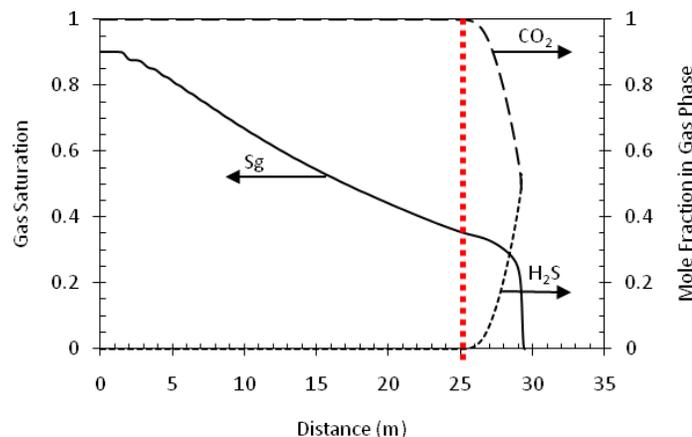


Figure 3: Variation in mole fraction of H_2S in gas phase after 100 days ($k=5$ D; injection rate= 1000 scm^3/day). For this simulation the brine was assumed to be H_2S saturated, and therefore presents a worst-case scenario. Geochemical data suggests H_2S in the brine is in-fact significantly sub-saturated and thus the mole fraction in the real-world aquifer would be significantly reduced from what is shown here.

- 3) Construction of geostatistically-based reservoir models dependent on relationships between wireline resistivity/conductivity measurements and porosity/permeability. Sparse well-based data inhibited the use of more conventional rock-property indicators.

- 4) Modeling seismic attributes, e.g. acoustic impedance, to develop detailed characterizations for a focus area within the larger study region. Findings suggest no faulting in the study area with a time structure consistent with the regional NE-SW dip orientation; localized anomalies likely associated with dissolution in the overlying Wabamun; and the existence of favorable zones of low acoustic impedance and high bulk porosity.
- 5) Establishing an understanding of the basic geomechanics of the target formation and caprock seal including: modeling the post-geomechanical deformation (Fig. 4) and stress changes of CO₂ injection in the reservoir and caprock layers; investigating the possibility of increasing well injectivity by injection at fracturing pressure; studying the propagation of fractures and evaluating the risk of fracturing the caprock; and incorporating thermal effects into the geomechanical model and determining the effects of cooling due to injection on stresses, displacements, and fracture propagation.

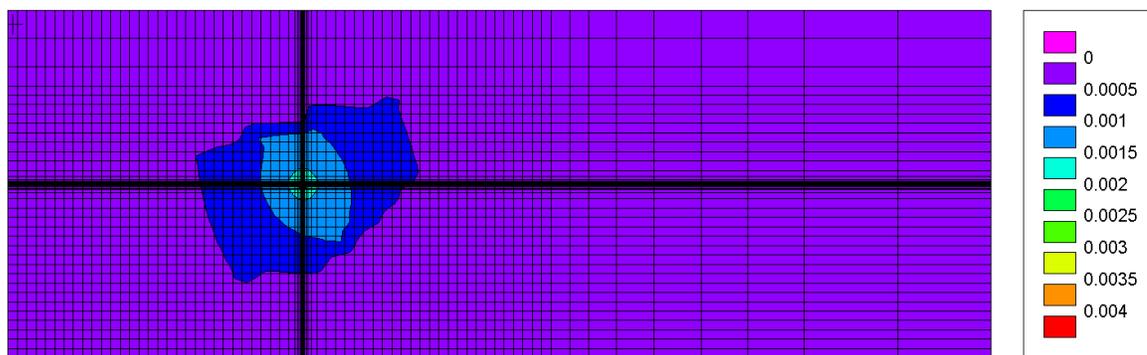


Figure 4: Vertical displacement (m) at ground surface after 50 years of injection at 1 Mt/yr below fracture pressure.

- 6) Review of land and pore space ownership in the study area, along with regulatory statutes of CCS in Alberta.

Future Work

- Brine compositions in the WASP database are based on simple sampling methods that do not preserve the dissolved gases at reservoir conditions. Consequently, bottom hole sampling, or sampling through surface separators, are required to better determine reservoir compositions of dissolved gases. Proper planning of a CO₂ storage project relies on this information.
- Available seismic data have not been typically shot with the saline aquifer (in this case the Nisku Fm.) as the primary target. Coverage and vintage issues are also a factor limiting options for interpretation and modeling.
- Available core from the cap rock (Calmar Fm. shale) and underlying seal (Ireton Fm. shale) are not adequate due to the age, often > 40 years old, and highly desiccated nature. Proper geomechanical analysis requires fresh core.
- Various in-situ test programs are needed to assess geothermal effects on the fracturing of reservoir and cap rock and actual leakage rates through compromised cement behind casing and/or poor abandonment jobs. Intentionally designed test wells and testing sites are vital.

- Pressure management of the injection plume is critical. To that end, DST's and core need to be taken from aquifers that are above and below the target sequestration site. Early on in the development of saline aquifer sequestration sites, characterization needs to address seal quality as much as the actual injection reservoir. Carefully planned and designed vertical pressure transient interference tests to determine the effective vertical permeability are vital for modeling of vertical CO₂ plume movement and evolution.
- The deepest potential sequestration formations in the WASP region, such as the Basal Cambrian sandstone, also need to be fully appraised as potential CO₂ storage targets. The lack of financial incentives to explore these formations could result in better injection targets being overlooked.

Conclusions

The first phase of the WASP project was about characterization - what data are available, the interpretation and integration of those data, and predictions of system behavior during and after large-scale injection into a saline aquifer. The next phases of WASP will focus on acquiring data to compensate for the deficiencies listed above. A set of recommended test programs for wells intentionally drilled as test-wells and/or CO₂-injectors are identified and mathematically modeled. The analysis of these tests will facilitate improvements in the design of future large scale CO₂ sequestration projects. As the rapidly growing industry for the geological storage of CO₂ is nascent, it is necessary and appropriate to lay out strategies to deal with data deficiencies specific to these projects now.

Acknowledgements

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