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Geological Carbon Storage Assessment of the Mackenzie Delta Basin, Northwest Territories

Integrated Reservoir Characterization, Storage Capacity, and Preliminary Injectivity Evaluation

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Introduction

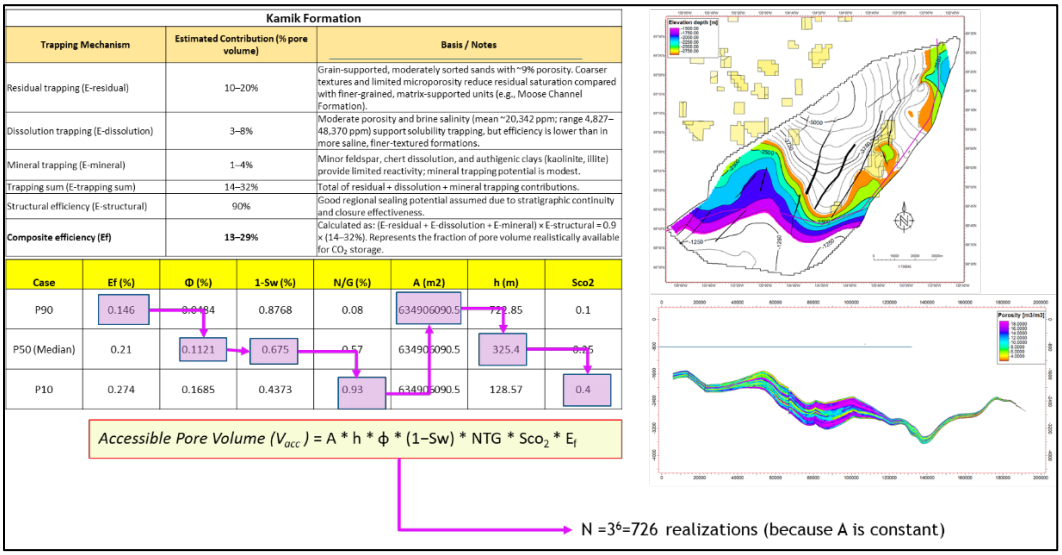
Geological Carbon Storage (GCS) is a critical enabler for achieving long-term emissions reductions in hydrocarbon-producing and energy-exporting regions. In northern Canada, the Mackenzie Delta Basin represents a strategically important yet under-evaluated opportunity for large-scale CO_2 storage, given its thick sedimentary succession, regionally extensive sandstone reservoirs, and proximity to potential future industrial emission sources. This study presents a basin-scale assessment of CO_2 storage potential in the Mackenzie Delta Basin, integrating geological characterization, petrophysical analysis, structural interpretation, volumetric capacity estimation, and preliminary injectivity evaluation.

Reservoir characterization

Four stratigraphic intervals were identified as candidate storage reservoirs based on depth, lithology, reservoir continuity, and available subsurface data: the Moose Channel Formation (Cretaceous fluvial–deltaic sandstones), the Kamik Formation (Lower Cretaceous marine to marginal-marine sandstones), the Bug Creek Formation (Jurassic sandstones with localized reservoir development), and the Mount Clark Formation (Cambrian heterogeneous sandstones). The evaluation integrates legacy wireline logs, laboratory petrophysical measurements, core and thin-section petrography, 2D seismic interpretation, and regional geological synthesis.

Reservoir characterization reveals significant variability in porosity, permeability, and net-to-gross (NtG) across the assessed formations, reflecting depositional texture, matrix content, compaction, and diagenetic modification. Grain-supported, moderately sorted sandstones with limited clay matrix preserve the highest effective porosity and permeability, whereas matrix-rich and lithic-dominated intervals exhibit reduced reservoir quality and connectivity. Probabilistic NtG distributions were developed to capture uncertainty in effective reservoir thickness and lateral continuity (Figure 1). The Kamik Formation generally exhibits moderate-to-high NtG and favourable petrophysical characteristics, while the Moose Channel Formation displays greater internal heterogeneity. The Mount Clark Formation shows lower effective NtG due to tighter fabrics and increased heterogeneity.

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Kamik Formation

Trapping Mechanism	Estimated Contribution (% pore volume)	Basis / Notes
Residual trapping (E-residual)	10–20%	Grain-supported, moderately sorted sands with ~9% porosity. Coarser textures and limited microporosity reduce residual saturation compared with finer-grained, matrix-supported units (e.g., Moose Channel Formation).
Dissolution trapping (E-dissolution)	3–8%	Moderate porosity and brine salinity (mean ~20,342 ppm; range 4,827–48,370 ppm) support solubility trapping, but efficiency is lower than in more saline, finer-textured formations.
Mineral trapping (E-mineral)	1–4%	Minor feldspar, chert dissolution, and authigenic clays (kaolinite, illite) provide limited reactivity; mineral trapping potential is modest.
Trapping sum (E-trapping sum)	14–32%	Total of residual + dissolution + mineral trapping contributions.
Structural efficiency (E-structural)	90%	Good regional sealing potential assumed due to stratigraphic continuity and closure effectiveness.
Composite efficiency (Ef)	**13–29%**	Calculated as: (E-residual + E-dissolution + E-mineral) × E-structural = 0.9 × (14–32%). Represents the fraction of pore volume realistically available for CO_2 storage.

Case	Ef (%)	Φ (%)	1-Sw (%)	N/G (%)	A (m2)	h (m)	Sco2
P90	0.146	0.0484	0.8768	0.08	634906090.5	722.85	0.1
P50 (Median)	0.21	0.1121	0.675	0.57	634906090.5	325.4	0.35
P10	0.274	0.1685	0.4373	0.93	634906090.5	128.57	0.4

Figure 1. Static storage capacity parameterization for the Kamik Formation showing P10, P50, and P90 stringing of key geological and petrophysical inputs used in volumetric CO_2 capacity estimation.

Data Interpretations and Modelling

Structural interpretation of regional seismic data indicates variable fault density and compartmentalization across the basin, including the influence of the Husky Lake Fault zone. Both faulted and unfaulted structural scenarios were considered to account for uncertainty in lateral pressure dissipation and plume migration. Thick mudstone- and shale-dominated intervals overlying the candidate reservoirs are interpreted to provide effective containment, with no evidence for regionally pervasive leakage pathways at the scale of available data.

Static CO_2 storage capacity was estimated using a modified U.S. Department of Energy (DOE) volumetric methodology incorporating formation thickness, area, porosity, NtG, in-situ CO_2 density, and storage efficiency factors. Results highlight a pronounced contrast between the Moose Channel and Kamik formations. The Moose Channel Formation exhibits relatively modest and well-constrained storage potential, with probabilistic estimates ranging from approximately 5 Mt CO_2 (P10) to 30 Mt CO_2 (P90) and a median value of ~20 Mt CO_2 (P50), consistent with more limited reservoir thickness and lateral continuity. In contrast, the Kamik Formation demonstrates substantially larger but more uncertain storage potential, with static capacity estimates ranging from ~71 Mt CO_2 (P10) to ~2.1 Gt CO_2 (P90) and a median estimate of ~1.4 Gt CO_2 (P50). The wide spread between percentile cases underscores the sensitivity of volumetric capacity to NtG, porosity, and effective reservoir extent within the Kamik interval.

Preliminary injectivity was evaluated using near-well numerical simulations conducted with the TOUGH3 reservoir simulator EOS7C equation-of-state module. A one-dimensional radial model

was constructed to represent dense-phase CO_2 injection into a saline sandstone reservoir, using the Kamik Formation as a representative test case. Simulation results indicate stable early-time injection behaviour at rates consistent with commercial-scale CCS operations, characterized by localized near-well pressure buildup, effective radial pressure dissipation, and no transition to unfavourable multiphase flow regimes (Figure 2). Dissolution of CO_2 into the aqueous phase contributes to pressure moderation and limits free-phase gas accumulation near the wellbore (Figure 3).

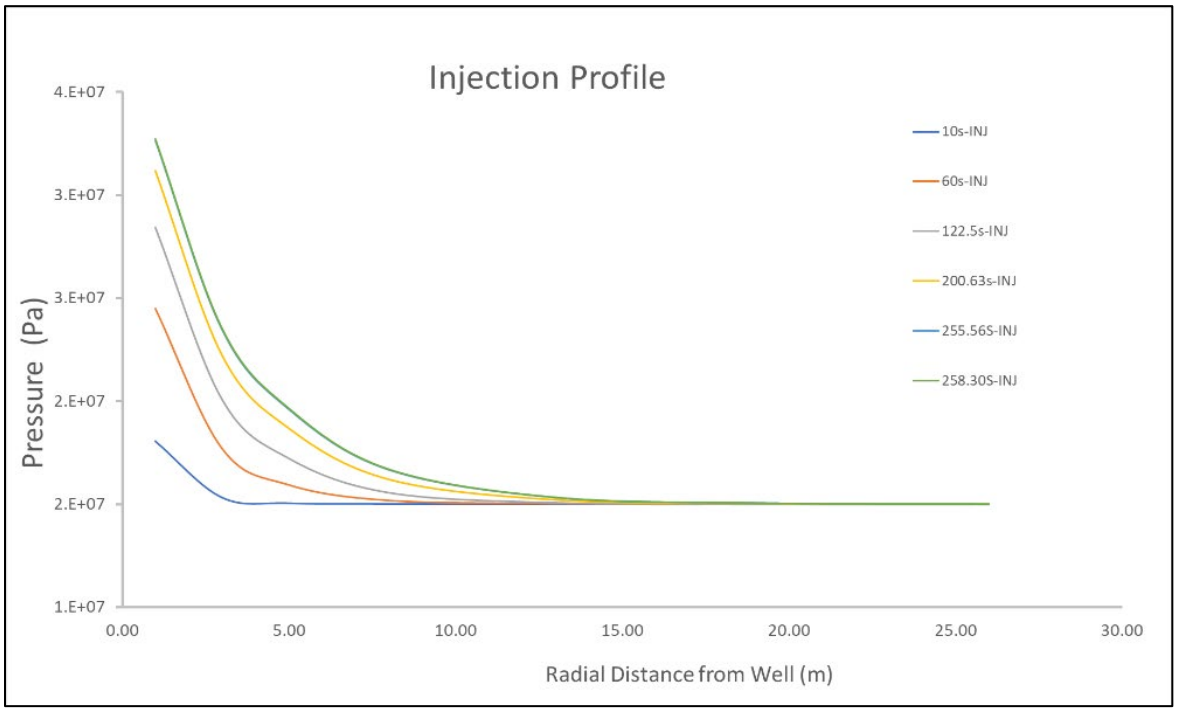


Figure 2. Pressure distribution as a function of distance from the injection well (X), illustrating near-well pressure buildup and radial pressure dissipation during dense-phase CO_2 injection.

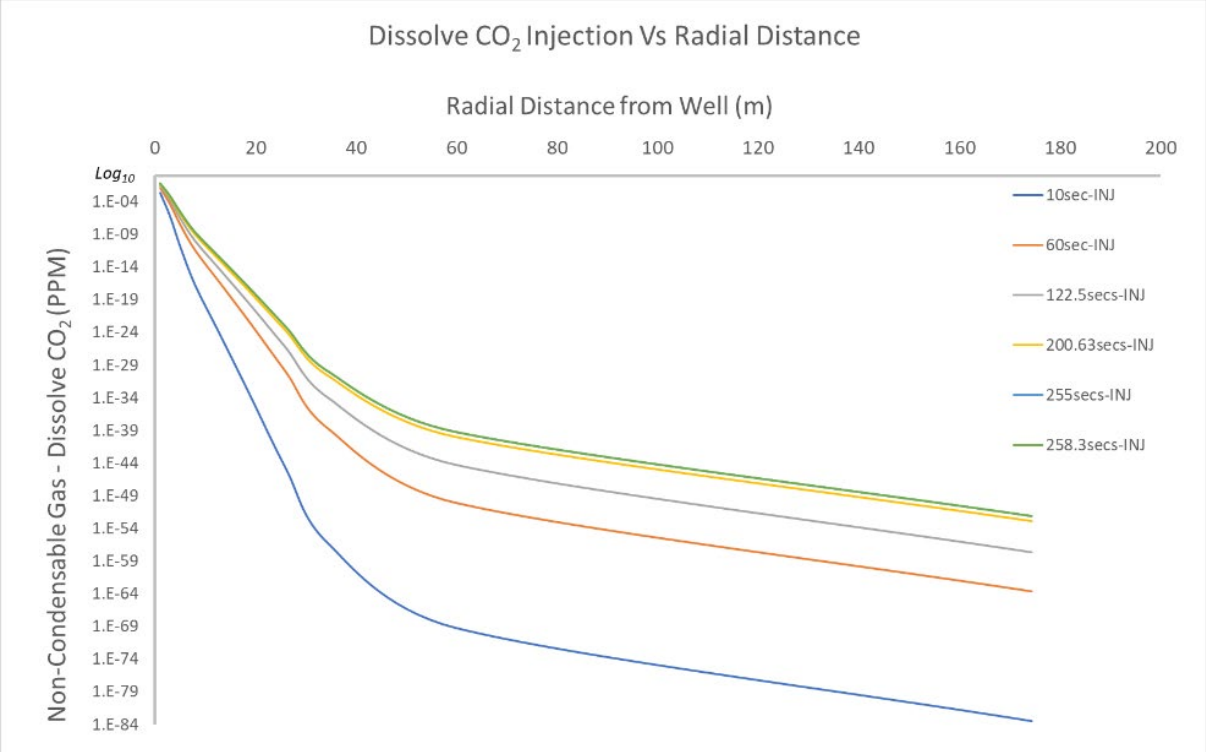


Figure 3. Spatial distribution of the liquid-phase non-condensable gas mass fraction (X_NCG_L) as a function of distance from the injection well (X), illustrating near-well CO_2 enrichment and radial attenuation under dense-phase injection conditions.

Summary

Overall, the results demonstrate that the Mackenzie Delta Basin possesses significant potential for secure geological CO_2 storage. While the Moose Channel Formation may support localized or pilot-scale deployment, the Kamik Formation emerges as a regionally significant storage target based on its large probabilistic capacity, reservoir continuity, and favourable injectivity performance. The study supports advancement from basin-scale screening toward appraisal-level assessment and provides a robust technical foundation for future CCS planning in northern and remote sedimentary basins.