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# Subsurface Risk Assessment Workflow for $CO_2$ Storage in Saline Aquifer Site Screening: Case Study From the New York Appalachian Basin

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## Abstract

Consistent site screening workflows for $CO_2$ storage in saline aquifers is necessary to optimize site selection for subsurface storage complexes. For early-stage projects, a typical screening workflow should involve both volumetric modeling and a subsurface risk assessment, mirroring the established volumetric risk assessment workflows that are used in conventional petroleum exploration. Here we present a flexible, scalable subsurface risk assessment workflow that is used for early-stage site screening of subsurface $CO_2$ storage in saline aquifers as well as an example case study of the workflow applied to a potential storage site in upstate New York's Appalachian Basin.

Subsurface risk is assessed across three categories: reservoir, confinement, and injectivity, each of which is broken up into subsequent risk elements. The reservoir risk elements are reservoir presence and reservoir quality; confinement elements are seal presence, seal quality, structural leakage potential and trap geometry; the injectivity elements are injection capacity, pressure limitation, and induced seismicity. In the workflow, each risk element is scored from 0-1.0 with higher numbers representing higher relative risk and the risk element scores are plotted on a spider plot that communicates overall project subsurface risk profiles and allows for the quick comparison across several projects.

We present a case study for a site screening in the Appalachian Basin for a target reservoir in the Potsdam Fm, a Cambro-Ordovician reservoir that has been studied previously as a potential carbon storage unit. The critical risks for the injection into the Potsdam in the study area are capacity and pressure limitation, with risk scores of 0.7 & 0.8 respectively.

## Introduction

Systematic risk assessment is essential for CCUS project success, yet standardized workflows for early-stage site screening remain inconsistent across the industry. The petroleum industry has used volumetric risk assessment workflows for decades (Rose, 2001), but analogous frameworks for CO2 storage site screening are not widely adopted. Early-stage CCUS projects often face limited subsurface data and require workflows that accommodate varying data quality while enabling portfolio-level comparisons across multiple sites.

This talk presents a flexible, scalable subsurface risk assessment workflow for early-stage screening of $CO_2$ storage sites in saline aquifers. The workflow adopts petroleum risk exploration methodologies to $CO_2$ storage requirements, providing a semi-quantitative framework for site comparison.

A case study for this workflow is presented in the Upstate New York Appalachian Basin. A screening site was assessed in the area around the town of Geneseo that could serve as a storage site for regional $CO_2$ emissions (Figure 1). This part of the Upstate New York Appalachian Basin has been the target of historical natural gas production, primarily from the Silurian Medina formation sandstone (Hartnagel, 1938). Because of the low permeability of the Medina formation (0.1 md), it is commonly hydraulically stimulated for gas production and is not a viable sequestration reservoir target. Deeper Cambro-Ordovician sands in the Knox group were screened as potential targets for this study (Konstantinovskaya, 2023).

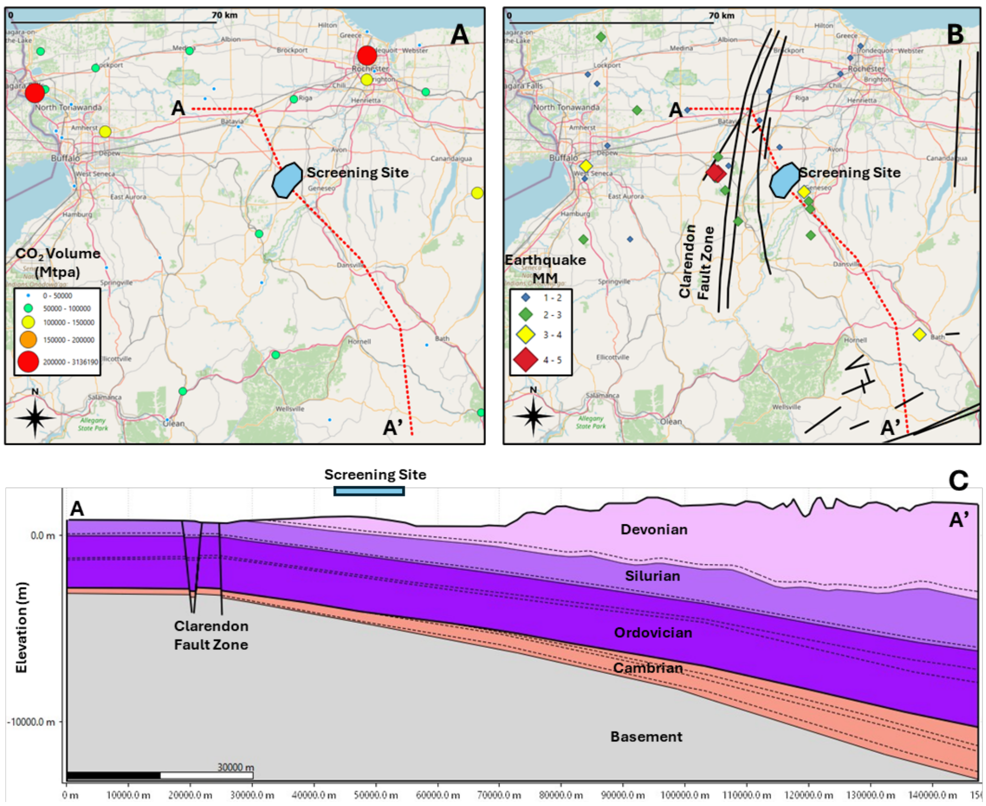


Figure 1. A- Map showing regional $CO_2$ sources (circles), screening site location (blue polygon), and location of cross section in Figure 1C (red dashed line). B- Map showing historical seismic from United States Geological Survey historical catalog (USGS, 2024) in diamonds, location of screening site (blue polygons), mapped geological faults (black lines), and location of cross section in Figure 1C (dashed red line). C- Cartoon cross section modified from Trippi et al., (2019). Dashed gray lines represent sandstone units that can be potential $CO_2$ storage reservoirs. Approximate screening site location extent at surface shown by blue bar.

## Methods

Subsurface risk is organized into three primary categories, each with specific risk elements that are evaluated to the extent possible given available data:

*Reservoir Risk:*

- Reservoir Presence – lateral continuity and thickness of target formation
- Reservoir Quality – porosity and permeability characteristics

*Confinement Risk*:

- Seal Presence – lateral continuity and thickness of sealing units
- Seal Quality – lithologic integrity and ductility of seal
- Structural leakage potential – faulting and fracturing
- Trap Geometry – structural configuration controlling lateral migration potential.

*Injectivity Risk:*

- Injection Capacity – ability to accommodate required injection rates (number of wells)
- Pressure Limitation – constraints imposed by formation salinity, depth, and regulatory limits
- Induced Seismicity – potential for triggering seismic events based on fault proximity

Each risk element is scored from 0-1.0, as a relative likelihood of technical underperformance or containment failure, where 0 represents negligible risk and 1.0 represents high likelihood of failure under expected operating conditions. Scores are assigned and reviewed by the subsurface team and subject matter experts, and individual scores are averaged to minimize bias (Surowiecki, 2005). Scores from 0.0–0.3 represent low relative likelihood of failure based on available data; 0.4–0.6 represent moderate likelihood reflecting either suboptimal properties or elevated uncertainty; and 0.7–1.0 represent high likelihood where data indicate unfavorable conditions or unacceptable uncertainty.

Risk elements are visualized using spider plots, where each radial axis represents one risk element and the distance from the origin indicates the risk score. This visualization enables rapid identification of critical risk factors, facilitates portfolio-level comparison across multiple sites, and provides intuitive communication of risk elements to stakeholders.

A preliminary reservoir characterization of the Knox Group sandstones (Potsdam Fm.) was conducted from the literature and interpretation of offset well logs. This reservoir characterization was accompanied by volumetric modeling using the EASiTool analytical reservoir simulation software (Ganjdanesh, R., and Hosseini, 2017) and an evaluation of regional geological data.

**Results**

A summary of the risk assessment results is:

- **Reservoir Presence (0.3)**: Potsdam Fm. sandstones generally pinch out towards the north, but regional cross sections suggest reservoir still exists under the screening site. Offset wells suggest at least 50 ft. of reservoir sand is present.
- **Reservoir Quality (0.5):** Porosity ranges from 4-12%. Permeability ranges from 3-30 md.
- **Seal Presence (0.2):** Multiple competent seals are present, including the Utica shale.
- **Seal Quality (0.2):** Seals are laterally extensive and thick. Top seal is Utica shale, which is undeveloped for oil and gas in the area, so it has not been compromised by hydraulic stimulation.
- **Structural Leakage Potential (0.5)** Site is near but doesn't intersect Clarendon Fault Zone.
- **Trap Geometry (0.3):** Shallow dip to the north (< 2°). No major migration is present in model.
- **Capacity (0.7):** Single well in Potsdam formation is modeled to accommodate 133,000 Mtpa of $CO_2$. Multiple wells would be needed for some sources that emit >300,000 Mtpa.
- **Pressure Limitation (0.8):** Modeling suggests that injections wells are pressure limited.
- **Seismicity (0.5):** A Magnitude 4.6 earthquake occurred on Clarendon Fault Zone, west of the screening site. Magnitude 2-3 earthquakes occurred southeast of the site (USGS, 2024).

## Discussion

The total subsurface risk was quantified through an internal team risking exercise and is shown in Figure 2. The scores represented on the spider diagram are the average of scores from multiple subsurface geoscientists and engineers garnered through expert elicitation. Scores were assigned independently by using a standardized scoring rubric and shared dataset. Element scores were averaged within each discipline to reduce individual bias; however, final interpretation preserves disciplinary accountability, with domain-specific experts retaining primary authority over their respective elements. This workflow is intended for early-stage screening; detailed project sanction decisions should rely on discipline-specific technical evaluations and integrated modeling.

For the site in this study, pressure limitation and capacity were the highest risk elements scored at 0.8 and 0.7 respectively. Elements related to seismicity and faulting were ranked as medium risk due to the proximity of Clarendon fault zone and historical earthquakes outside of the screening site. The lowest risk elements relate to the presence and quality of a competent and laterally extensive sealing formation.

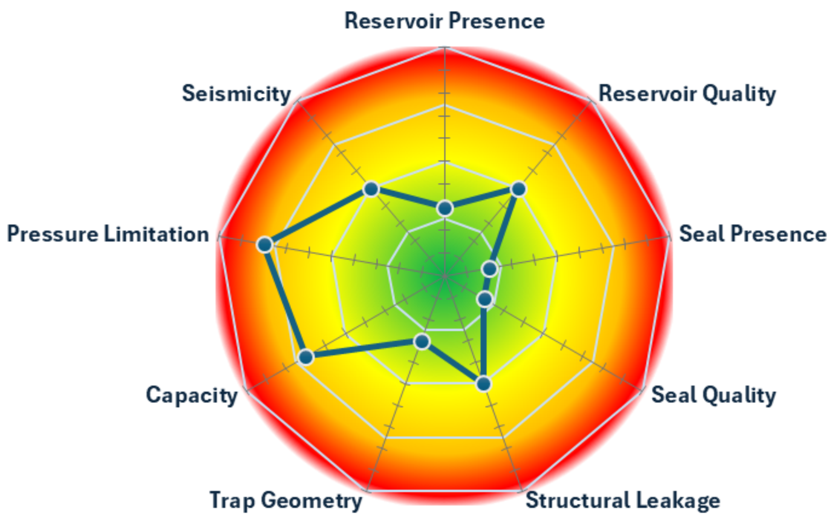


Figure 2. Spider plot of subsurface $CO_2$ storage risk for the screening site in this study.

## Conclusions

A consistent, transparent subsurface risk assessment workflow is critical for early-stage screening of saline aquifer $CO_2$ storage sites, particularly where subsurface data are sparse and uncertainty is high. The workflow presented here adapts established petroleum exploration risking methodologies to CCUS applications, enabling semi-quantitative comparison of storage sites across a project portfolio. By structuring risk into reservoir, confinement, and injectivity categories and scoring individual risk elements through expert elicitation, the approach provides a repeatable and scalable framework that can evolve as additional data become available.

Application of the workflow to a screening site in the Appalachian Basin targeting the Cambro–Ordovician Potsdam Fm. demonstrates its practical utility. The case study highlights pressure limitation and storage capacity as the dominant risks for the site, while seal presence and quality represent comparatively low risk. Visualization of these results using spider plots allows for rapid identification of critical risk drivers and clear communication of subsurface uncertainty to technical and non-technical stakeholders.

Overall, this workflow supports informed decision-making during early CCUS project phases by prioritizing data acquisition, guiding site selection, and facilitating portfolio-level comparisons. As CCUS deployment accelerates, adoption of standardized, flexible risk assessment methodologies such as this will be essential for improving project screening efficiency and reducing subsurface uncertainty.

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