Introduction

Malaysia has the potential to be a significant player in the large-scale decarbonization of Asia (Woodmac, 2023). Central Luconia, offshore Malaysia, is top ranked for subsurface geological CO_2 storage given the multitude of proven productive reservoirs (carbonates and clastics) and effective top seals. In particular, the relatively undeformed Miocene sedimentary sequence provides CO_2 storage optionality in both depleted hydrocarbon fields and regional saline aquifers.

These geological CO_2 stores could be considered for future enablement of the development of contaminated gas resources and as the sink for domestic and international industrial CO_2. While the regulatory framework is still shaping up, Shell's integrated approach to risk identification and mitigation in Carbon Capture & Storage (CCS) projects has been applied to a Miocene carbonate depleted field opportunity. This approach has been used for projects such as QUEST and Northern Lights (e.g. Brown et al., 2023).

Shell's Five Pillars of CCS

Shell considers five pillars of geological CO_2 storage (Figure 1), with each representing a key component that must be assessed for a potential site, including: Capacity & Injectivity, Containment, Transport, Monitoring & Remediation and Stakeholders. Failure of any one pillar will prohibit a successful development. This contribution will in particular focus on capacity, containment and monitoring. The three are tied through the assumption that there is no capacity without containment and conformance assurance by applying monitoring techniques such as 4D seismic.

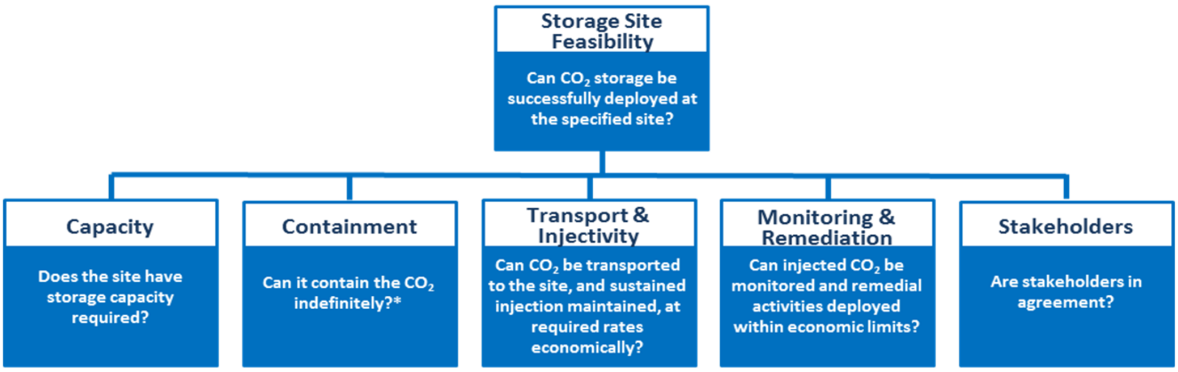

Figure 1 *Shell's five pillars of CCS, screening criteria and performance requirements for geological CO_2 storage.*

Risk-based CO_2 storage assessment

In this contribution, we will present an established approach to the typical containment risks posed by potential future storage in a Central Luconia Miocene isolated carbonate platform, based on a detailed assessment of the local and regional geology. For the risk assessment, bowties have been used that clearly identify and showcase a top event (leakage of CO_2), the threats and consequences and any preventative and mitigating barriers that could be invoked or implemented (Tucker et al., 2013). An example of the applied bowtie approach to risk assessment for a generic caprock is shown in Figure 2. replicated on other equivalent stores. The communalities between different stores in terms of their geology ensures at least partial replicability of the CO_2 storage assessment. Lessons learned from one store assessment can be applied to fasten the process for other similar stores.

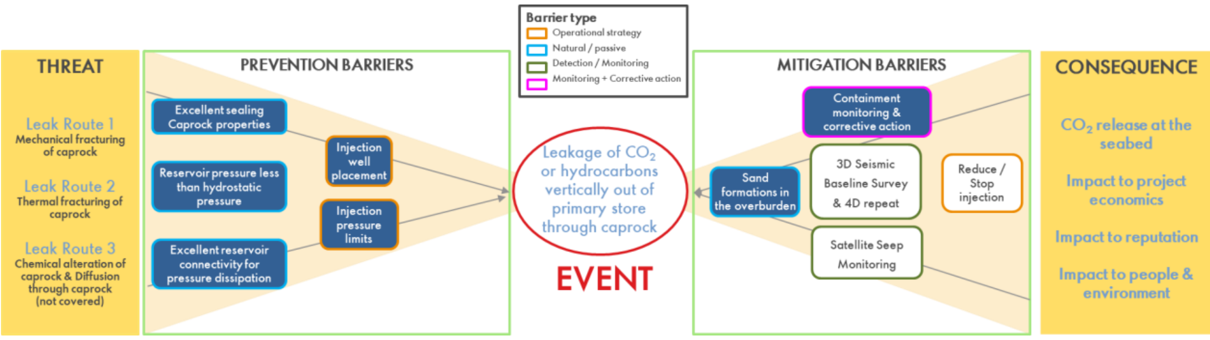

***Figure 2**: Typical bowtie example for potential caprock leak as top event.*

The plumbing diagram, originally used in the oil and gas industry as a way to focus subsurface teams on what matters for flow, provides an excellent tool to communicate CO_2 storage risks in the context of containment and capacity and to link a monitoring plan to the containment risks. The use of a conceptual plumbing diagram for a typical Miocene isolated carbonate platform (Figure 3) proved an excellent tool to understand and communicate potential tortuous leak paths, combining in one image the man-made legacy wells and potential natural leak paths in a single image.

Although containment risk assessment is typically site specific, the isolated carbonate platforms in Central Luconia share quite a few common risk elements such as a halo of normal faults related to differential compaction in the overburden, Cycle V sands, karst collapse features and historical legacy wells. These communalities allow to speed up the process of risk assessment by immediately focusing on the elements that matter.

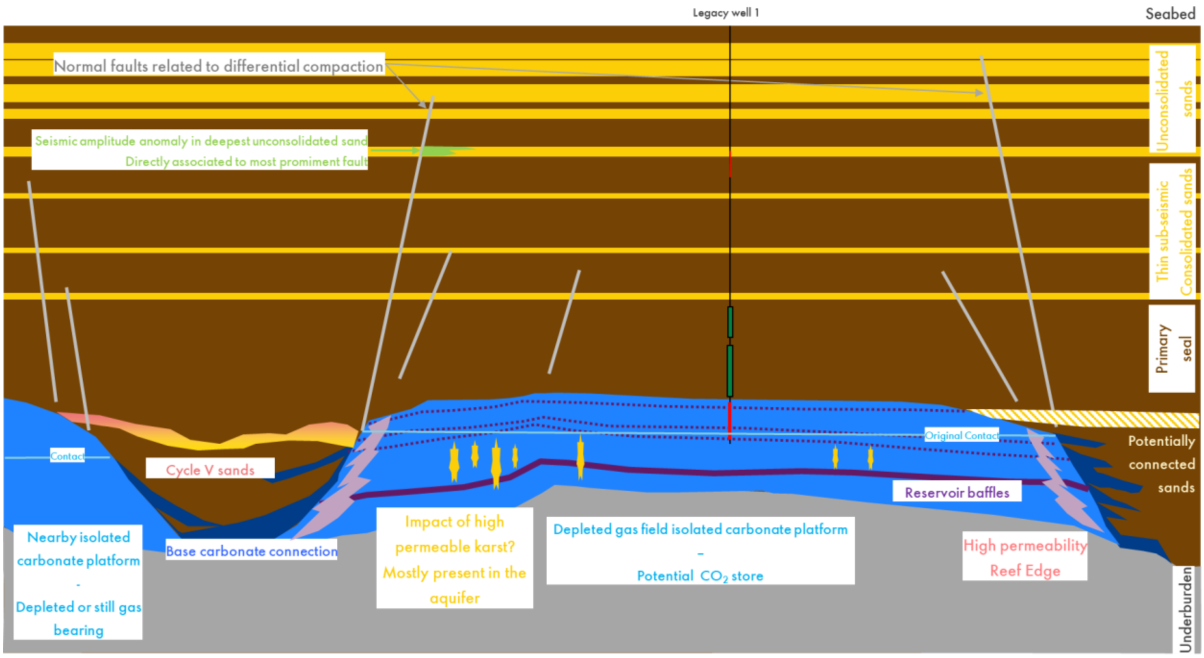

***Figure 3:** Conceptual plumbing diagram for an isolated carbonate platform in Central Luconia. Note the implementation of legacy well and geological information, focused on the store, its overburden and any more regional connections such as nearby reservoirs.*

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Conclusions

Plumbing diagram and bow-tie risk assessment workflows are useful tools to illustrate and demonstrate a comprehensive understanding of the potential containment risks, and the preventive and mitigation controls against their respective causes and consequences. These methodologies are used as a part of integrated approach to risk identification and mitigation in CCS projects, through which a foundation of confidence in the viability and robustness of the project can be established.

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