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Classification and Calibration of Legacy Well Risks for CO2 Storage in the Gulf Coast Basin

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Abstract

Large-scale CO_2 storage in the Gulf Coast Basin requires high confidence in long-term containment, particularly as more than fifty commercial-scale storage projects are currently planned or under development across the region. One of the main uncertainties is the presence of more than one million legacy oil and gas wells, many of which were drilled before modern construction and abandonment standards. These wells may create potential pathways for pressure or fluid migration, but current risk classification methods are often inconsistent, qualitative, and not calibrated with real operational evidence. This study evaluates how legacy well risk is defined across CCS research and compares these approaches with UIC injection practice. Historical well control records are used to examine whether classification assumptions match real well behavior. Results show that risk is often overestimated when uncertainty is treated as failure and when wells are screened without confirming hydraulic relevance. Most recorded incidents are operational rather than long-term integrity failures, while failures relevant to containment occur less frequently. The study supports a shift toward pathway-based, evidence-informed classification to improve containment risk evaluation in mature storage regions.

Introduction

The Gulf Coast Basin is one of the most important regions for geologic CO_2 storage because of its thick sedimentary formations, widespread sealing units, and long history of subsurface fluid injection. This long development history has also left a large population of legacy wells across the basin, introducing uncertainty for long-term containment performance. Legacy wells are often considered the primary engineered risk in CO_2 storage because they may bypass confining layers and allow pressure or fluids to migrate vertically. Many older wells lack complete documentation, were drilled before modern cementing standards, or may have experienced casing degradation over time. Because of this uncertainty, current

CCS risk frameworks frequently classify large numbers of wells as potential risks even when physical migration pathways are not confirmed. A key challenge is that CCS classification approaches vary widely and are rarely calibrated using real field evidence. Without calibration, uncertainty can lead to over-screening, excessive monitoring, and unnecessary mitigation. This study evaluates how legacy well risk is defined and whether classification assumptions reflect realistic leakage potential.
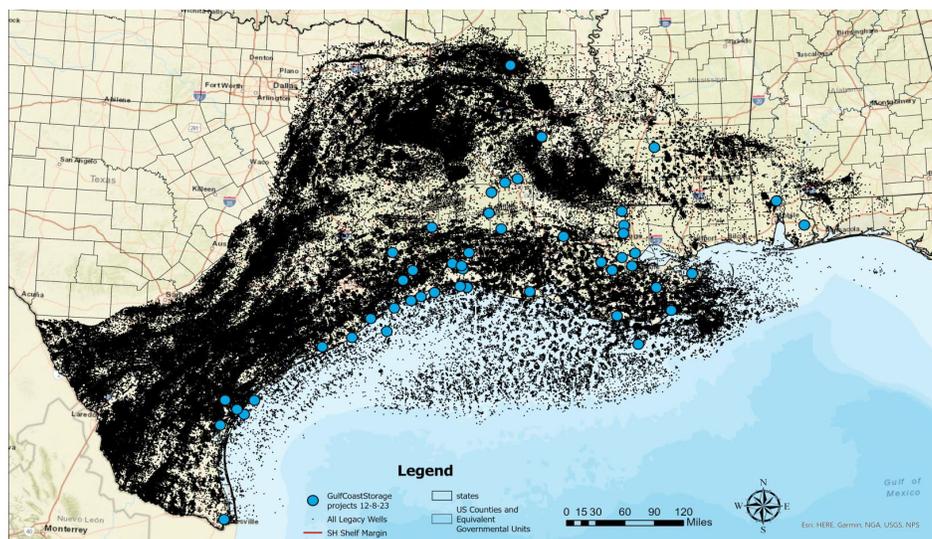

Figure 1. Distribution of Legacy wells and CO2 storage projects areas in the Gulf of Mexico (compiled from IHS data)

Theory and/or Methods

The study combines comparative framework analysis with historical failure evaluation. First, multiple CCS legacy well risk frameworks were reviewed to identify common risk factors and differences in how leakage risk is defined. These were compared with UIC injection screening logic, where risk is evaluated based on whether a well can realistically transmit fluids or pressure to a protected formation. Second, wells were conceptually screened based on hydraulic relevance, including pressure communication, intersection with injection intervals, and spatial relationship to the pressure footprint. The influence of uncertainty and incomplete documentation was also evaluated. Third, historical well control data from the Texas Railroad Commission were analyzed to distinguish operational incidents from failures relevant to long-term containment. This comparison helps determine whether classification assumptions match real-world well behavior and provides observational grounding for evaluating leakage risk.

Results

Two key findings emerge from the analysis. First, CCS literature and regulatory injection practice define legacy well risk differently. Many CCS frameworks focus on uncertainty, aging, and documentation gaps, while UIC screening evaluates whether a realistic migration pathway exists. Under pathway-based logic, wells without hydraulic connection to the injection system are screened out even if documentation is incomplete. This approach reduces overestimation of risk and focuses attention on physically relevant wells. Second, historical incident analysis shows that operational failures dominate the well control record. Most events are related to drilling operations, offset fracturing, or external damage, while failures directly related to long-term containment such as corrosion, geologic integrity breach, or spontaneous

brine flow occur less frequently. These integrity-related failures are episodic rather than persistent. Together, these results suggest that legacy well risk may be overestimated when classification relies primarily on uncertainty rather than physical migration potential.
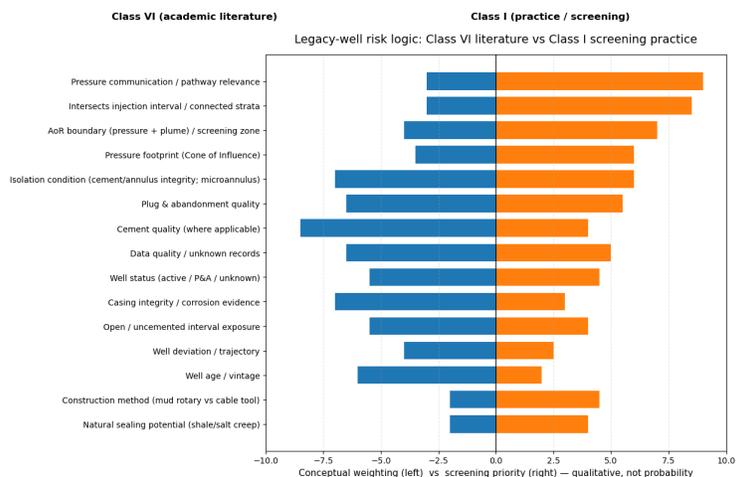

Table 1. Legacy well risk logic: Class VI literature vs UIC Class I screening practice
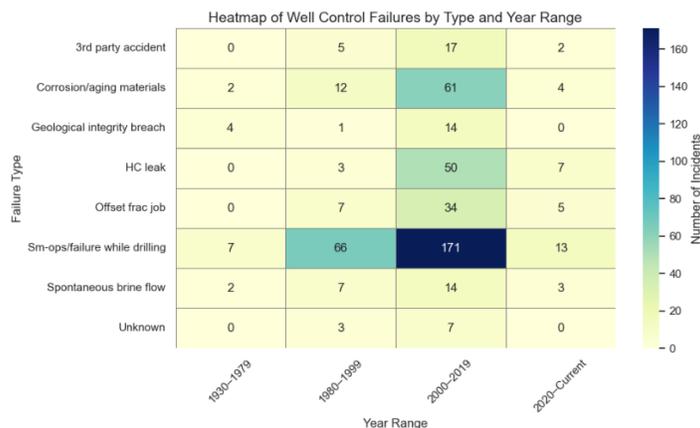

Table 2. Distribution of well control failure types by year range

Discussion

The comparison highlights a key conceptual difference between CCS classification frameworks and injection practice. Regulatory injection screening prioritizes pathway realism, while many CCS frameworks emphasize uncertainty and theoretical degradation. When uncertainty is treated as failure, large well populations may be flagged as risks even without physical evidence. This over-screening can increase monitoring costs, complicate permitting, and create inflated perceptions of containment risk. Incorporating pathway-based screening and real-world failure evidence can improve classification accuracy and focus mitigation efforts on wells that truly pose migration risk. The findings support moving from qualitative, uncertainty-driven approaches toward evidence-informed classification grounded in hydraulic relevance and operational behavior.

Conclusions

Legacy wells remain a key uncertainty for CO_2 storage, but current classification approaches often overestimate risk by relying heavily on uncertainty rather than physical evidence. Historical incident data show that most failures are operational, while long-term containment failures are comparatively rare. A pathway-based, evidence-calibrated classification approach can improve risk prioritization, reduce unnecessary mitigation, and strengthen confidence in CO_2 storage containment. This approach provides a more realistic framework for evaluating legacy well risk in mature basins such as the Gulf Coast.

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