AAPG HEDBERG CONFERENCE
"Geological Carbon Sequestration: Prediction and Verification"
August 16-19, 2009 – Vancouver, BC, Canada

Assessing and Quantifying Risks in Geological Carbon Sequestration Projects Using RISQUE Methodology with a Modified Delphi Approach to Reduce Uncertainty

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The geological storage and sequestration of CO_2 produced by the burning and utilization of fossil-derived fuels and feedstock's is considered one of the primary solutions to a clean energy future. Concepts associated with the geological storage of many materials such as natural gas in gas storage fields, the deep underground injection of hazardous wastes, and deep geologic storage of hazardous radioactive material are well known. The utilization of CO_2 as an oil reservoir secondary or tertiary enhanced recovery method is also well known as is oil and gas reservoir modeling and development. However, the deep injection of CO_2 into depleted oil and gas reservoirs and brine formations is perceived as a high-risk situation requiring a variety of complex regulatory and technical licensing and risk evaluations. In countries with complex regulatory structures (the US for example) the siting of geologic sequestration facilities may require a long-lead time, public involvement 'many voices' approach similar to those now used in NEPA requirements. The utilization of the RISQUE methodology has had success in geological carbon sequestration (Bowden and Rigg, 2004). The inclusion of a modified Delphi approach with the RISQUE methodology can assure that all technical involvement is included in the risk evaluation process and compress the traditional NEPA-type schedule into the shorter RISQUE schedule while at the same time increasing the public scientific and technical input into the overall RISQUE process.

The Delphi process was originally developed in the 1950's by researchers at the Rand Corporation as a tool for forecasting future events (Custer et al, 1999) using questionnaires with controlled-option feedback. More recently, in a modified form, the Delphi process is often used for technology evaluations and as an analysis mechanism for a broad variety of complex concepts. Basically, it involves bringing experts together in teams to generate, then evaluate and rank, concepts under time and consensus constraints. These expert teams may then be reformed into independent teams to re-evaluate and rank the initial concepts, compare rankings to achieve consensus, re-evaluate if necessary, and present a scoring of best concepts based on the iterative expert review process. Basically, multiple experts, in variable teams, develop 'best-estimate' informed rankings. This program is well defined in the literature, used by major commercial and government organizations, and provides a well-known rigor to the expert evaluation and ranking process. The RISQUE process is defined in Bowden and Rigg (2004). Figure 1 demonstrates the concept of using a modified Delphi process in conjunction with the RISQUE process.

Established uncertainties in geological carbon sequestration include geological, financial (market), regulatory, legal, and technology parameters. All are interdependent and variable but can be addressed by expert analysis using both RISQUE and Delphi approaches. The RISQUE approach concentrates on expert input but the modified Delphi approach can use both expert and informed consensus input. For example, for USDOE funded or supported geosequestration projects Technology Readiness Assessments (and other technical review such as External Technical Reviews) may be necessary at the Conceptual Design -1 (CD-1) (Alternative Selection), CD-2 Performance Baseline, and CD-3 (Construction Start) events (DOE, 2008). The US Government Accounting Office has recently found that some technologies in DOE programs have not been sufficiently evaluated to work as intended (GAO, 2007). This conceivably adds an unacceptable element of risk. The RISQUE process does not routinely include a continual and progressive technology risk component but the modified Delphi process could address this potential need.

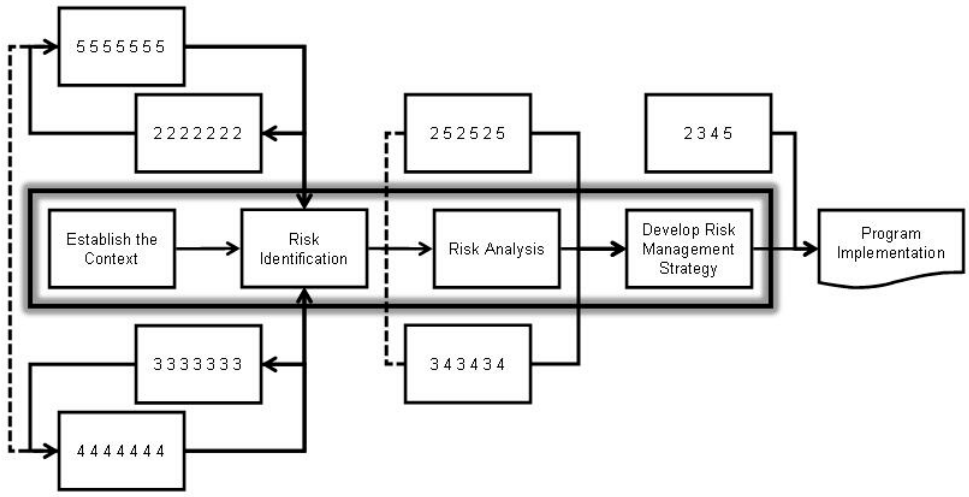

Figure 1 - Concept block diagram showing the primary RISQUE approach (shaded box) with the proposed modified Delphi process. Timing proceeds from left to right. In this concept, the RISQUE process proceeds normally using an expert panel for risk context and identification support. In addition, a Delphi approach using various stakeholder groups is also used, operating under typical Delphi constraints (debate, time, re-iterative agreement, and consensus) and feeding in to the RISQUE method at the Risk Identification step. Representatives from the Delphi groups form second round Delphi teams that feed the RISQUE analysis and modeling step. A single Delphi team, made from the remaining representatives supports the finalized Strategy. The input from the Delphi teams is weighted against the expert panel input according to pre-determined criteria.

The combined RISQUE-Delphi concept includes the following thoughts. Consistent with the Australian experience, one or more potential geological sequestration sites, with relevant and variable technological, legal, financial, regulatory, and geologic uncertainties. The geologic variables are typically the most understood in terms of concept (for example see Kaldi, 2008) and presumed storage reservoir detail (for example see recent reservoir analysis by Bhattacharya et al, 2008, Esposito et al, 2008). Actual storage capability is a probable uncertainty (DOE-NETL, 2008a). Legal issues are an uncertainty (DOE-NETL, 2006), location, implying financial, regulatory, and market issues may be an uncertainty (see discussions in DOE-NETL, 2008b). Injection uncertainties, certainly a part of the overall risk evaluation and involved in all other uncertainties are considered in recent draft USEPA requirements (EPA, 2009). If we visualize these uncertainties existing in a ‘risk-space’ then we have multi-dimensional aspects of variable

risks potentially applicable at differing times in our process towards developing a siting risk uncertainty model and workable sequestration plan. The RISQUE addresses the risks but in a linear scheme whereas in complex programmatic settings the risks are considered typically in a non-linear scheme, basically as interveners or stakeholders choose to utilize them. The modified Delphi technique, if well planned and implemented, can possibly bring all elements of risk, presumably from the non-linear 'risk-space' into a controlled input for the RISQUE process. The modified Delphi technique can quantify and qualify the risks perceived by others into a set of consensus risks, in a re-iterative agreement process, and weight those factors against the expert panel of the RISQUE process. As the RISQUE process proceeds, the Delphi re-iterative process continues using smaller subgroups and continued quantified and qualified weighted input.

This approach accomplishes several goals. First, the chance of a risk review becoming lost in the technical details of the reservoir analysis is greatly reduced. The inclusion of external technical experts in the stakeholder Delphi teams can help prevent this possibility. Second, because of their independent nature, each Delphi team might approach the problem by using various features, events, processes (FEP) concepts in their development of scenarios, conceptual models, and potential consequence analysis. This would insure that a broader range of technical, legal, regulatory, and financial risks are used in the RISQUE model. Third, Delphi teams with specific emphasis on key topics, such as containment issues, could improve the model input from the RISQUE expert panel and add an element of ongoing peer review in the whole process. This could be true for many of the potential Delphi teams. Fourth, but not finally (in any potential Delphi process the results can be surprising), Delphi teams for unique sequestration conditions, for example, offshore state or federal lands versus onshore, can be formed to provide unique expert input into the overall RISQUE expert input. Overall, by combining the RISQUE approach with a modified Delphi approach, both expert and stakeholder concerns are progressively addressed so that the end product is workable and the chance of success, in all uncertainty areas, is higher.

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