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Quantitative decision analysis for CO_2 storage conformance management: A synthetic case study at Smeaheia, North Sea

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Abstract

In order to make large-scale CO_2 storage feasible, prospective operators must report tailored short and long-term Measurement, Monitoring, and Verification (MMV) strategies to verify conformance, containment, and ensure early detection of potential undesired effects such as pressure build-up anomalies in the storage complex. Non-conformance events might result in large additional costs associated with the operation and in some cases in the operation being stopped entirely.

Monitoring can represent a significant part of storage costs. Optimal design of monitoring programs therefore needs to consider the trade-off between value and cost. How to define conformance, what technology to use, when and how often we should monitor are all important questions to ask. But the answers are not trivial due to uncertainties and complex interaction effects. In addition, such considerations are case specific (Furre et al., 2017).

To answer some of these questions, a risk-based approach can be adopted (Dean and Tucker, 2017). Another possibility is using value of information (VOI) analysis. The VOI framework allows the decision maker to perform an evaluation of data gathering options before any information is purchased. It assumes a decision problem and calculates the value of additional information obtained by acquiring data before making the decision. Application examples in earth science disciplines are described in Eidsvik et al. (2015). Studies in the context of CO_2 storage monitoring are discussed in Sato (2011), Barros et al, (2018), and Anyosa et al., (2019).

In this work, we propose to use a value of information (VOI) analysis framework (Barros et al., 2018) to analyze and evaluate possible actions to ensure conformance of CO_2 storage operations. Our case study is based on a modified sector model from Smeaheia, a location being considered for a full-scale capture and CO_2 storage (CCS) project in the North Sea. Compared to the original model made available, one of the main faults is artificially extended to create two reservoir compartments. The considered injection well location is in the northern compartment as shown in Figure 1. The north and south boundaries are modelled as open (to represent a large connected aquifer volume) using production wells operated at constant bottom-hole pressures. The east and west boundaries are closed. We assume that the main uncertainties are related to the properties of the internal fault (transmissibility multiplier) and to the reservoir petrophysical properties (permeability, porosity). If the fault transmissibility is lower than anticipated, it will impact on the long-term storage capacity due to a more rapid pore pressure increase than in the Expected

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Evolution Scenario (EES). An increase in the pore pressure along the fault will also increase the risk of a fault reactivation, which could lead to creation of a leakage pathway. Assuming those uncertainties, several scenarios are simulated for a given injection period to track how the pressure builds up over time at the injector location and along the fault.

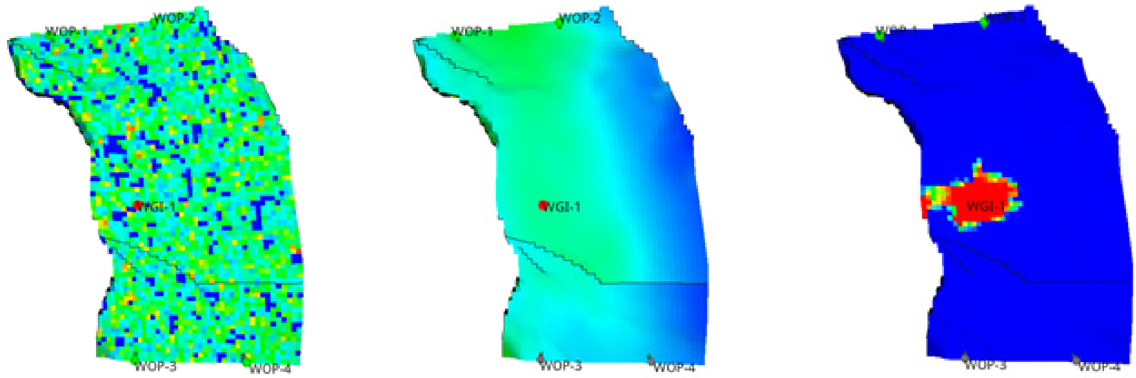

Figure 1: Permeability distribution (left) and state of the reservoir at 20 years of CO_2 injection for the Smeaheia case with extended fault assumed to be completely sealing: pressure (middle) and gas saturation distribution (right)

We study how a decision tree covering conformance management options for operators can be built. We define a conformance criterion and investigate different action scenarios leading to different values for the operators (see example in Figure 2). We discuss through examples how such values can be defined in monetary units. In a second stage, we perform a sensitivity study to evaluate (i): the effect of our predefined cost assumptions on the optimal action, and (ii): the effect of uncertainties in the gathered information about pressure at the fault location. We finally discuss through examples how geophysical monitoring can be integrated to help ensure pressure conformance.

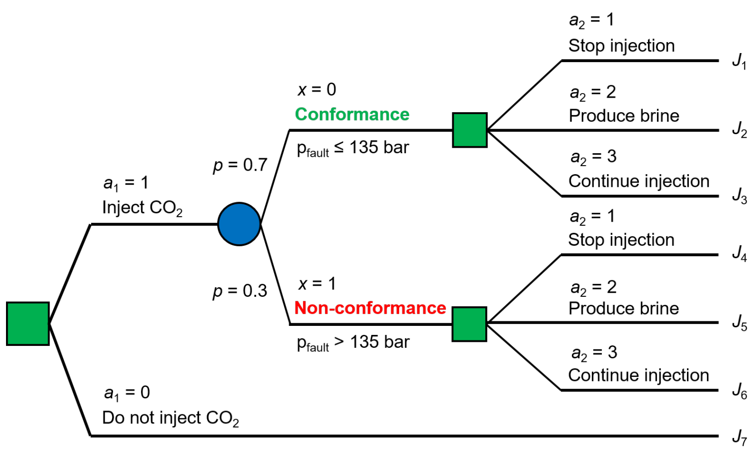

Figure 2: Example of a decision tree covering the conformance management options for operators of the proposed Smeaheia case study. Green squares represent decision nodes and blue circle correspond to chance nodes. The value of each alternative (J values) must be quantified for the decision tree to be solved.

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