OPTIMIZATION OF GEOLOGICAL CARBON SEQUESTRATION USING SEMI-ANALYTICAL LEAKAGE MODELS LINKED TO A MULTI-OBJECTIVE EVOLUTIONARY ALGORITHM

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Geological carbon sequestration has the potential to reduce anthropogenic carbon dioxide (CO2) emissions while cleaner, more sustainable energy solutions are developed. This technology does however present a risk that CO2 may intrude into and adversely affect groundwater resources. While CO2 intrusion typically does not directly threaten underground drinking water resources, it may cause secondary effects, such as the mobilization of hazardous inorganic constituents present in aquifer minerals and changes in pH values. Therefore, thorough risk analysis must be a performed at the start of any geological carbon sequestration project.
Balancing project resources and leakage risk is essential in designing a geological sequestration project. This paper attempts to optimize the number of CO2 injection wells, injection rates, and injection well locations for a given site by (a) minimizing the total project cost, the summation of major project costs with the cost associated with CO2 leakage; and (b) maximizing the mass of injected CO2, for a given proposed sequestration site. The capital and operational costs of injection wells are directly related to injection well depth, location, injection flow rate, and injection duration. The cost of leakage is directly related to the mass of CO2 leaked through weak areas, such as abandoned oil wells, in the cap rock layers overlying the injected formation. Additional constraints on fluid overpressure caused by CO2 injection are imposed to maintain predefined effective stress levels that prevent cap rock fracturing. Two semi-analytical models are used to estimate mass leakage and fluid overpressure.
These semi-analytical leakage flow models are coupled with a multi-objective evolutionary algorithm to determine Pareto-optimal trade-off sets giving minimum total cost vs. maximum mass of CO2 sequestered. Trade-off curves are developed for multiple fictional sites with the intent of clarifying how variations in domain characteristics (aquifer thickness, aquifer and weak cap rock permeability, the number of weak cap rock areas, and the number of aquifer-cap rock layers) affect Pareto-optimal fronts. Accuracy and computational cost associated with using each semi-analytical leakage model are explored and discussed.