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Hydro-mechanical pressure response to fluid injection into finite aquifers highlights the non-local behavior of storage

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Specific storage reflects the volumetric deformation capacity of permeable media. Classical groundwater hydrology equals elastic storage to medium compressibility, which is a constant-in-time and locally-defined parameter. This allows simplifying the flow equation into a linear diffusion equation that is relatively easy to solve. However, the hydraulic gradients, generated by fluid injection or pumping, act as forces that push the medium in the direction of flow causing it to deform, even in regions where pressure has not changed. Actual deformation depends on the elastic properties of the medium, but also on aquifer geometry and on surrounding strata, which act like constraints to displacements. Therefore the storage results to be non-local (i.e. the volume of water released at a point depends on the poroelastic response over the whole aquifer) and the proper evaluation of transient pressure requires acknowledging the hydro-mechanical (HM) coupling, which is generally disregarded by conventional hydrogeology. Here we discuss whether HM coupling effects are relevant, which is of special interest for the activities of enhanced geothermics, waste disposal, CO_2 storage or shale gas extraction.

We propose analytic solutions to the HM problem of fluid injection (or extraction) into finite aquifers with one-dimensional or cylindrical geometries. We find that the deviation respect to traditional purely hydraulic solutions is significant when the aquifer has limited capacity to deform. The most relevant implications are that the response time is faster and the pressure variation greater than expected, which may be relevant for aquifer characterization and for the evaluation of pressure build-up due to fluid injection.