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Hydraulic and mechanical effects on tide-induced head fluctuation in coastal aquifer systems

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The study of the dynamic relation between sea tides and coastal groundwater using analytical models has received much attention since the 1950s. Most analytical solutions only consider hydraulic effects and have been derived for aquifer systems that end at a coastline. In the present study, an exact analytical solution is derived to describe tide-induced head fluctuation in an aquifer system that extends a finite distance under the sea. The proposed model incorporates mechanical effects originated by the elastic compression and expansion of the porous formations. The aquifer system consists of a horizontal leaky confined aquifer cover by a semipermeable layer. The analytical solution is a generalization of the solutions obtained by Li and Jiao (Analytical studies of groundwater-head fluctuation in a coastal confines aquifer overlain by a semi-permeable layer with storage, Adv. in Water Resour., 24:565-573, 2001) and Li, Li and Boufadel (The enhancing effect of the elastic storage of the seabed aquitard on the tide-induced groundwater head fluctuation in confined submarine aquifer systems, J. of Hydrology, 350:83-92, 2008), that consider zero and infinite extensions of the aquifer system under the sea, respectively. An important advantage of the derived analytical solution is that it allows to separately compute the mechanical and the hydraulic components of groundwater head fluctuations. The mechanical effect is generated by the fluctuations of sea level that elastic compress and expand the offshore portion of the aquifer system. On the other hand, the hydraulic effect is due to the direct interaction between sea water and groundwater at the submarine outlet of the confined aquifer. The impact of mechanical and hydraulic effects is illustrated through a hypothetical example. The mechanical component of the total tide-induced head fluctuation is significant for aquifers that extend intermediate and large distances under the sea. This component increases the amplitude of the total head fluctuation and tends to synchronize the phase of the sea tide with the phase of the groundwater fluctuation. Then we can conclude that the observation of large fluctuations in coastal boreholes cannot be indicative of good hydraulic connection between the seawater and groundwater. Ignoring the mechanical effect will lead to significant errors in predicting tide-induced head fluctuation and in estimating hydraulic parameters from measurements of groundwater fluctuations.