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Physical and numerical modeling of seawater intrusion in coastal aquifers

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Seawater intrusion in coastal aquifers is a worldwide problem caused, among others factors, by aquifer overexploitation, rising sea levels, and climate changes. To limit the deterioration of both surface water and groundwater quality caused by saline intrusion, in recent years many research studies have been developed to identify possible countermeasures, mainly consisting of underground barriers. In this context, physical models are fundamental to study the saltwater intrusion, since they provide benchmarks for numerical model calibrations and for the evaluation of the effectiveness of general solutions to contain the salt wedge.

This work presents a laboratory experiment where seawater intrusion was reproduced in a specifically designed sand-box. The physical model, built at the University of Padova, represents the terminal part of a coastal aquifer and consists of a flume 500 cm long, 30 cm wide and 60 cm high, filled for an height of 49 cm with glass beads characterized by a d_{50} of 0.6 mm and a uniformity coefficient $d_{60}/d_{10} \approx 1.5$. The resulting porous media is homogeneous, with porosity of about 0.37 and hydraulic conductivity of about 1.3×10^{-3} m/s. Upstream from the sand-box, a tank filled by freshwater provides the recharge to the aquifer. The downstream tank simulates the sea and red food dye is added to the saltwater to easily visualize the salt wedge. The volume of the downstream tank is about five times the upstream one, and, due to the small filtration discharge, salt concentration variations (i.e., water density variations) due to the incoming freshwater flow are negligible. The hydraulic gradient during the tests is constant, due to the fixed water level in the two tanks. Water levels and discharged flow rate are continuously monitored.

The experiment presented here had a duration of 36 h. For the first 24 h, the saltwater wedge was let to evolve until quasi stationary condition was obtained. In the last 12 h, water withdrawal was carried out at a depth of 7 cm and at a distance of about 50 cm from the downstream tank by means of a draining trench. The experiment was monitored by means of photos collected with regular frequency as well as ERT (electrical resistivity tomography) with a joint surface and cross-borehole configuration, specifically designed for the laboratory flume. The experimental results are also compared with numerical simulations performed by the SUTRA software.