Coupled Navier-Stokes And Darcy Flow Modelling For In-well Groundwater Investigation.

Marti Bayer-Raich[1], A. Credoz[2], T. Osorno[3], S. Jordana[4], N. Nief[2], B. Ducastel[2], J. Guimerà[4], J.F. Devlin[3]

[1]Amphos21 Consulting, Barcelona, Spain
[2]TOTAL R&D, Lacq, France
[3]Department of Geology, University of Kansas, USA
[4]Amphos21 Consulting, Barcelona, Spain

Abstract

The objective of this work is to analyze measuring techniques used in observation boreholes to investigate natural groundwater flow (magnitude and direction). The In-Well-Point-Velocity-Probe (IWPVP) is a technique based on mini tracer tests performed inside observation boreholes to infer magnitude and direction of natural groundwater Darcy flux q in the surrounding aquifer. The proportionality between measured in-well velocity u and aquifer natural Darcy flux q for a specific IWPVP device (fixed geometrical parameters such as borehole radius, distance between tracer inlet and measuring point, width of IWPVP channels etc.) requires performing sandbox experiments in controlled conditions for different values of q. We aim to use COMSOL Multiphysics® models to simulate sandbox experiments for new geometrical designs of IWPVP so that the proportionality factors between u and q can be determined without the need of setting up sandbox experiments. Modelling the water flow through the IWPVP device requires coupling Darcy flux (in porous media) with Navier-Stokes flow (in the borehole and through the IWPVP channels). Flow modelling can provide water velocity in the IWPVP channels for variable channel orientation with respect to the direction of q. Results from the numerical models can provide valuable insight on different IWPVP designs before they are manufactured. Currently IWPVP are being produced with ABS (Acrylonitrile Butadiene Styrene) plastic through 3D printing, so geometrical changes and adaptation to different setting are relatively easy to implement. In our approach, sandbox experiments for different IWPVP devices (2´´ and 4´´ diameter) are used to validate the modelling methodology and compare simulation results with measured experimental data. Modelling starts with the simplest setting, which consists of a circular void in a 2D homogeneous aquifer. For this case, an analytical solution available indicates that the water velocity u at the center of the borehole is u=3q. We compare COMSOL Multiphysics® results with this analytical solution as a first step. When the IWPVP device is inserted in the borehole, the presence of the IWPVP itself causes a significant impact in the water flow within the borehole (compared to the case of an empty void). Water velocity increases considerably as water in the borehole can only pass through the IWPVP channels (which are 4.5 mm wide for both 2´´ and 4´´ IWPVPs). Experimental and modeling results when a channel is oriented in the flow direction indicate proportionality factors of u≈15q (experimental) and u≈21q (simulated) for the 2'' IWPVP and of u≈31q (experimental) and u≈41q (simulated) for the 4'' IWPVP. For the range of Darcy fluxes observed in the field (0.5 to 5 m/d) results from the numerical model are comparable in accuracy to those obtained in sandbox experiments. To obtain more accurate simulation results, preliminary simulations with 3D flow models accounting for the borehole screen geometry (screen slot opening, distance between slots and slot orientation) are being conducted.

Figures used in the abstract

Figures used in the abstract

Figure 1 : 3D model domain with symmetry planes to simulate flow through borehole screen and IWPVP.

Figure 2 : Velocity magnitude for screen slots oriented upstream.

Figure 3 : Velocity magnitude for screen slots oriented downstream.