Modeling a Nozzle in a Borehole

Ekkehard Holzbecher, Fengchao Sun
GZG, Applied Geology, Goldschmidtstr. 3, Göttingen, 37077

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Introduction: Within a borehole a nozzle can be installed in order to increase the efficiency of fluid injection. Figure 1 depicts the nozzle and the slotted filter screen. The local fluid velocity at and near the nozzle outlet in increased. The shape of the nozzle and the boundaries of casing and borehole play a role for the injection. Up to now there are no studies on the turbulent flow build-up in a vertical pipe due to a nozzle.

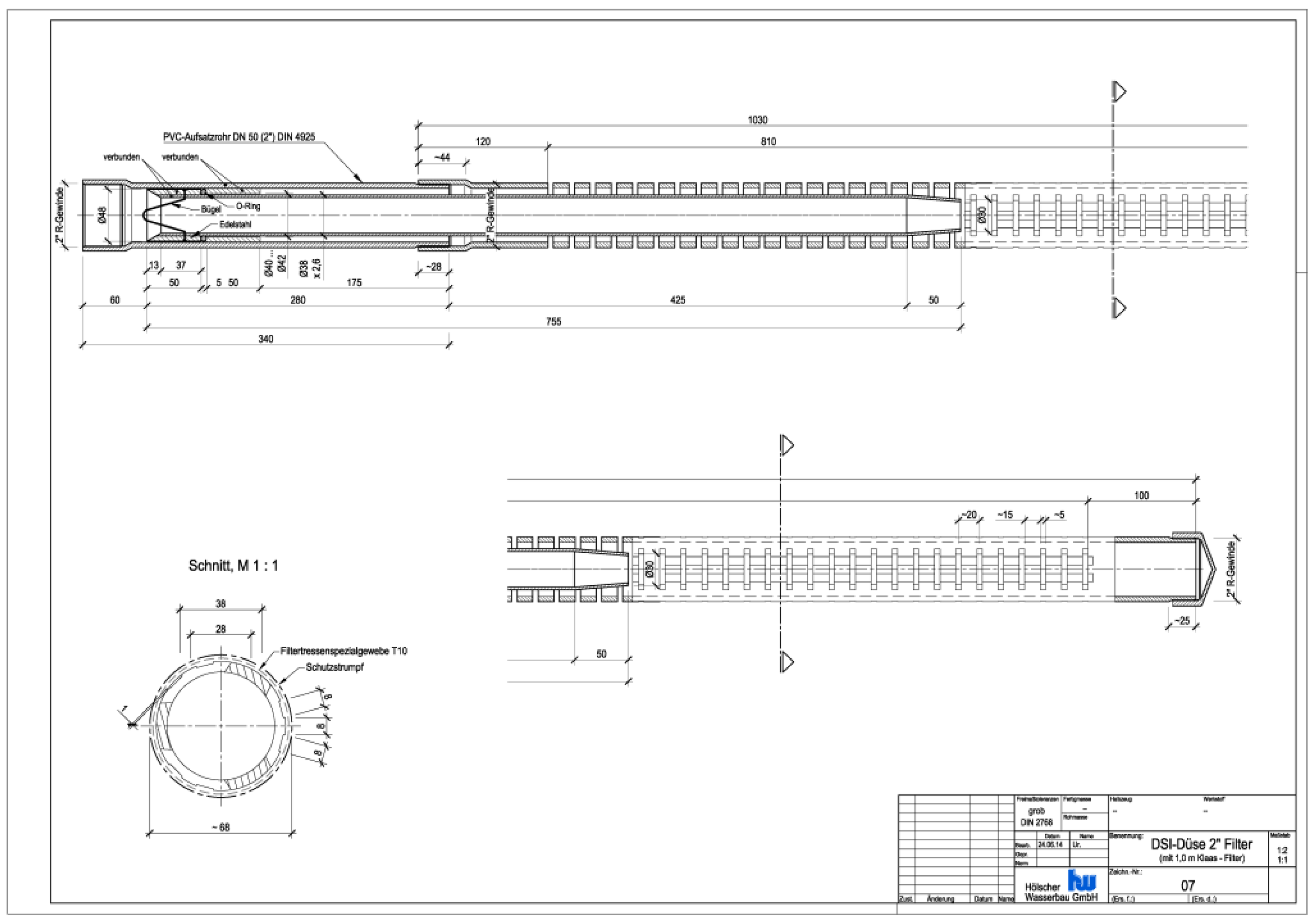

Figure 1. Nozzle and filter screen blueprint

Computational Methods: The model is based on the Navier-Stokes equations. Turbulence closures are the two-equation k-ε and k-ω approaches. We use constraints and boundary conditions, and wall functions close to walls. At outlets we specify pressure as Dirichlet conditions. In order to obtain appropriate distributions of k, ε, and ω at the inlet (top of Figure 2) a pipe model (not shown in Figure 2) is computed in a pre-run before the nozzle model. The result of the pipe model at the outlet is taken as inlet boundary condition for the nozzle.

Figure 2 shows a 2D model region in the axi-symmetric coordinate system, here for a slightly simplified nozzle/casing geometry. Flow is downward through the nozzle, with decreased cross-section. In the model the fluid leaves through nine slots in the perforated screen. Reference flow velocity is 30 m^3/h.

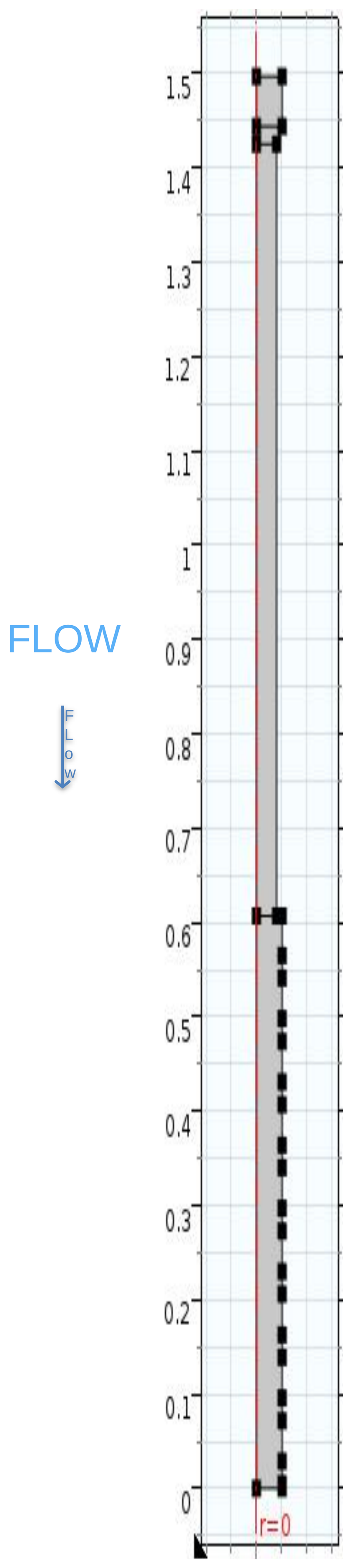

Figure 2. Sketch of model region

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Results: The k- ω method is much better than k- ε method to model the turbulent flow induced by a nozzle (Figure 3) . A fast jet with increased flow velocity develops within the nozzle (Figure 4). Figure 5 shows the flow field visualized by velocity size and streamlines. The share of outgoing flux for each outlet (from bottom to top) is shown in Figure 6. The outflow is unevenly distributed between the slots.

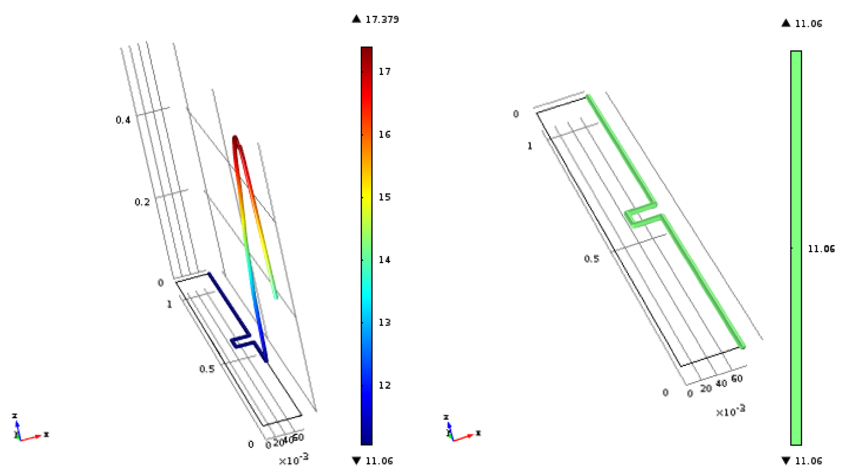

Figure 3. Wall lift-off, depending on turbulent closure; left: k-ε, right: k-ω

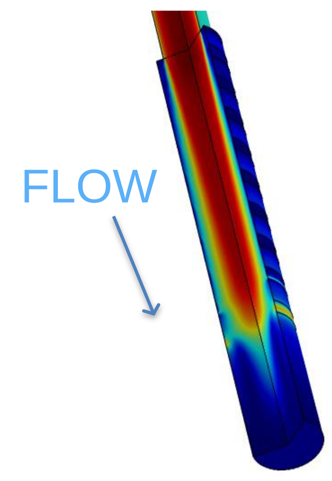

Figure 4. 3D view of flow between nozzle and casing, represented by velocity size (red = high, blue=low)

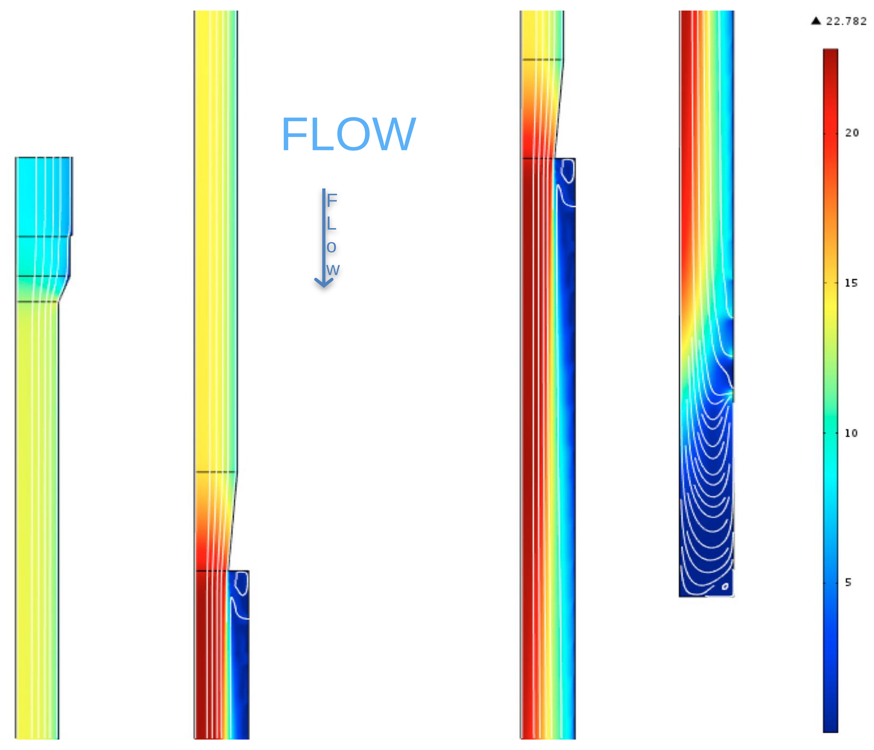

Figure5. Velocity size (color, [m/s]) and streamlines within the nozzle and casing

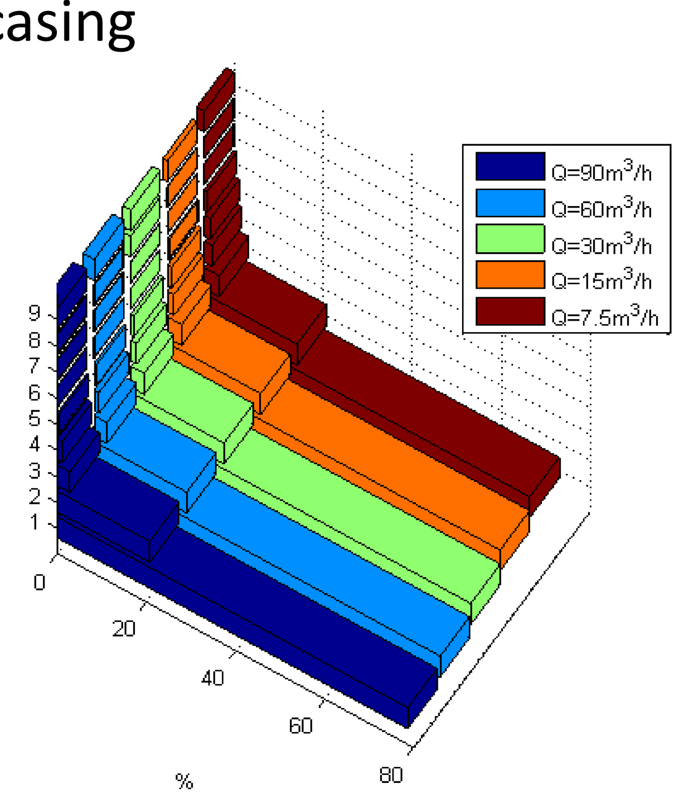

Figure 6. Contribution of outlets to total outflow (%); 1 is lowest, 9 is uppermost outlet

Conclusions: The outlet boundaries at the bottom play a dominant role concerning outflow. As the lower slots are unequally more relevant for the hydraulics of the entire installation, their position should be oriented on the more permeable layers within the porous medium. The results are of high importance for the practice of water injection into aquifers.

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