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Upscaling hydraulic conductivity from measurement-scale to model-scale

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The Geological Survey of the Netherlands systematically produces both shallow (< 500 m) and deep 3D geological models of the Netherlands. These models are predictions of geometry and properties of the subsurface, and are used in applied research. One of the geological models for the shallow subsurface (GeoTOP) consists of voxels of 100 x 100 x 0.5 m to a depth of 30-50 m below surface. For each voxel, lithostratigraphy, facies and lithological classes are modeled with geostatistical simulation techniques. These simulation techniques allow for the spatial uncertainty of the model results to be calculated.
One of the parameters that is subsequently assigned to the voxels in the GeoTOP model, is hydraulic conductivity (both horizontal and vertical).
Hydraulic conductivities are measured on samples taken from high-quality drillings, which are subjected to falling head hydraulic conductivity tests. Samples are taken for all combinations of lithostratigraphy, facies and lithology that are present in the GeoTOP model. The volume of the samples is orders of magnitude smaller than the volume of a voxel in the GeoTOP model. Apart from that, the heterogeneity that occurs within a voxel is not accounted for in the GeoTOP model, since every voxel gets a single lithology that is deemed representative for the entire voxel
To account for both the difference in volume and the within-voxel heterogeneity, an upscaling procedure is developed to produce up-scaled hydraulic conductivities for each GeoTOP voxel. A very fine 3D grid of 0.5 x 0.5 x 0.05 m is created that covers the GeoTOP voxel size (100 x 100 x 0.5 m) plus half of the dimensions of the GeoTOP voxel to counteract undesired edge-effects. It is assumed that the scale of the samples is comparable to the voxel size of this fine grid. For each lithostratigraphy and facies combination the spatial correlation structure (variogram) of the lithological classes is used to create 50 equiprobable distributions of lithology for the fine grid with sequential indicator simulation. Then, for each of the lithology realizations, a hydraulic conductivity is assigned to the simulated lithology class, using Sequential Gaussian Simulation, again with the appropriate variogram This results in 50 3D models of hydraulic conductivities on the fine grid. For each of these hydraulic conductivity models, a hydraulic head difference of 1m between top and bottom of the model is used to calculate the flux at the bottom of the model. No-flow boundaries is used on the sides of the model. In this way, difference in volume between sample-size and GeoTOP voxels and the internal heterogeneity within a GeoTOP voxel are accounted for.
An important product derived from assigning the upscaled hydraulic conductivities to the GeoTOP model is the hydraulic resistance of the Holocene confining layer. An example is presented, in which the calculation of the hydraulic resistance takes the uncertainty of the geological modelling into account. Comparison with results from pump-tests and experiences from users indicate that the upscaling and the subsequent calculation of hydraulic resistance of the Holocene layer yields reasonable results.