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Variogram based and Multiple - Point Statistical simulation of shallow aquifer structures in the Upper Salzach valley, Austria

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Quarternary sediments in overdeepened alpine valleys and basins in the Eastern Alps bear substantial groundwater resources. The associated aquifer systems are generally geometrically complex with highly variable hydraulic properties. 3D geological models provide predictions of both geometry and properties of the subsurface required for subsequent modelling of groundwater flow and transport. In hydrology, geostatistical Kriging and Kriging based conditional simulations are widely used to predict the spatial distribution of hydrofacies.

In the course of investigating the shallow aquifer structures in the Zell basin in the Upper Salzach valley (Salzburg, Austria), a benchmark of available geostatistical modelling and simulation methods was performed: traditional variogram based geostatistical methods, i.e. Indicator Kriging, Sequential Indicator Simulation and Sequential Indicator Co - Simulation were used as well as Multiple Point Statistics. The ~ 6 km^2 investigation area is sampled by 56 drillings with depths of 5 to 50 m; in addition, there are 2 geophysical sections with lengths of 2 km and depths of 50 m. Due to clustered drilling sites, indicator Kriging models failed to consistently model the spatial variability of hydrofacies.

Using classical variogram based geostatistical simulation (SIS), equally probable realizations were generated with differences among the realizations providing an uncertainty measure. The yielded models are unstructured from a geological point - they do not portray the shapes and lateral extensions of associated sedimentary units. Since variograms consider only two – point spatial correlations, they are unable to capture the spatial variability of complex geological structures. The Multiple Point Statistics approach overcomes these limitations of two point statistics as it uses a Training image instead of variograms. The 3D Training Image can be seen as a reference facies model where geological knowledge about depositional/erosional processes and geometric shapes of hydrofacies can be integrated. The Training Image can be constructed with object based Training Image generators which offer predefined geometric shapes for modeling sediment facies associations. Training Images can also be constructed in a Computer Aided Design (CAD) system. Non-uniform rational B-Splines are implemented in CAD systems and enable to generate even more realistic geometric shapes of sediment bodies than by means of object based training image generators. Multiple Point Statistics Simulation aims to produce local patterns from the Training Image and conditionally anchor them to the investigation data. Regarding geometric shapes and lateral extensions of derived sediment structures, the Multiple Point Statistics simulations yielded the most sensible hydrofacies models while reproducing input data proportions.