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Simulating regional groundwater transport to surface waters combining stream tube and hydrogeochemical approaches

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Deltas are among the most densely populated areas in the world and often suffer from water quality problems due to intensive agricultural land use. Transport of nutrients, metals and pesticides by shallow groundwater adds significantly to surface water quality problems. Therefore, regional groundwater transport modelling is increasingly used to evaluate scenarios which describe the effects of action programmes which aim to improve water quality. Regional scale transport models often require fine grid resolution to adequately simulate groundwater-surface water interaction. The fine grid resolution, however, limits opportunities for a thorough uncertainty analysis because of excessive computation times. Stream tube modelling is an alternative which allows for uncertainty analysis because computation times are limited even with fine grids.
We present a stream tube modelling approach which combines 3D flow path distributed modelling with 1D hydrogeochemical modelling and we compare the results with 3D transport modelling. We applied a novel MODPATH-option recently published in Groundwater (Visser et al. 2009) in order to produce reliable travel time frequency distributions for a lowland catchment with many weak sinks representing detailed drainage features. Three-dimensional travel time frequency distributions were obtained for specific land use-soil combinations in the catchment, which were then combined with 1D PHREEQC models in order to account for transport processes in the aquifers. The PHREEQC models correspond to representative subsurface columns for the land use –soil type combinations. Processes included cation exchange and nitrate induced pyrite oxidation. The breakthrough of nitrate, sulphate and nickel in the stream agrees well with an existing MT3D-model and with field data. Model uncertainty was assessed by evaluating (1) the uncertainty in the 3D flow field, (2) the spatially varying solutes recharge and (3) the vertically varying chemical transport parameters. The results indicate that the average depth of the chemical reaction zones is one of the most sensitive model parameters. The main advantage of the method, compared with regular 3-D transport models, is the fast computation time which enables a spatial uncertainty analysis using Monte Carlo or random field approaches.

Visser, A. R. Heerdink, H.P. Broers and M.F.P. Bierkens (2009) Travel time histograms derived from particle tracking in groundwater models containing weak sinks. Groundwater 47(2): 237-245