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A novel numerical technique for the high-precision simulation of flow processes related to artificial recharge

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This paper presents a novel numerical technique for large-scale groundwater flow simulations, in the frame of artificial recharge planning. The implementation is demonstrated using two test-sites from the EU funded GABARDINE project (FP6): The Sindos test site, near Thessaloniki, Greece, examines the infiltration of water towards the water table, through several unsaturated soil layers. The test site at Campina de Faro, Portugal, investigates phreatic surface movement around a large-diameter well. For both test cases a numerical simulation is constructed, and the local subsurface flow regime is investigated.

Numerical methods for solving PDEs using interpolation with radial basis functions (RBFs) will typically provide high accuracy solutions, achieve excellent convergence rates, and offer great flexibility with regards to the enforcement of arbitrary boundary conditions. However, RBF methods have traditionally been limited to the solution of small academic problems, due to issues of computational cost and numerical conditioning. Recent developments in locally supported RBF methods have led to techniques which can be scaled to the largest problem sizes, while maintaining many of the flexibilities of traditional RBF methods. As a contribution to the GABARDINE project, two such numerical techniques have been developed; the meshless LHI method and the control-volume based CV-RBF method. These numerical techniques are capable of modelling flow and transport in heterogeneous porous media, and are of order-N computational complexity, allowing problems to be solved on large and irregular datasets.

For both numerical techniques, the RBF Hermitian collocation method is utilised to perform interpolation at the local level, allowing the simultaneous imposition of pressure and mass-flux matching conditions at soil-layer interfaces. The non-overlapping stencil configuration then allows the accurate capture of non-smooth solution profiles across layer interfaces, to a high degree of accuracy [4,10]. Previous publications have verified the LHI and CV-RBF methods against analytical solutions obtained from several benchmark test-cases (see [1-10]), demonstrating highly accurate solutions in most cases. Procedures have also been demonstrated for the modelling of pumping and injection wells [8], infiltration ponds [2,6], and dynamic phreatic surfaces [8].

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