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Management of coastal aquifers using variable density models and neural network approximations

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Effective management of coastal aquifers is a highly complex problem and requires integration of mathematical models into optimization algorithms. The most advanced models to represent the highly complex non-linear coastal aquifer system are 3-D variable density models. Such models are computationally intensive and the overall time required for optimization can be exceptionally large and depends on factors such as the resolution of the model, the number of decision variables, etc. In order to expedite the process, it is proposed to approximate the 3-D variable density models by simpler models based on Artificial Neural Networks (ANN). The 3-D variable density finite difference model SEAWAT is used in this study and the idea is to approximate its behavior using ANN. The inputs to the ANN are the pumping rates of several wells, which correspond to the decision variables of the optimization. The outputs, used in the constraints of the optimization, are the distances between the wells screen and a reference iso-surface concentration level. The goal of optimization is to find the pumping rates of the wells which results in maximum withdrawal of freshwater from the aquifer, without degrading its quality. In real applications where the number of decision variables is large, the required initial input-output sample to train an ANN can be very large. A methodology is developed using Genetic Algorithms, where ANN are used as surrogate functions in order to find useful samples in the vicinity of the optimum solution. This methodology reduces significantly the size of the training sample resulting in reduction CPU time. In the case of 30 inputs and outputs an ANN with good generalization capabilities a close proximity to the optimum solution can be obtained using less than 400 samples, while using a randomly generated training data, the minimum number of samples must be of the order of 1000-2000. The methodology was applied to a coastal aquifer in Santorini Island. The optimum pumping

rates, obtained by the proposed method were compared to the results obtained using SEAWAT simulations and optimization by Sequential Quadratic Programming. The comparisons indicate that utilization of ANNs as surrogate functions to generate an initial sample and subsequent use of trained ANN in an optimization procedure, result to faster system optimization while the optimum solutions are very close to those obtained by SQP and SEAWAT.