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Multi-objective optimization of the management of a waterworks using an integrated well field model

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In Denmark 98 % of the fresh water used for private households, industry and irrigation comes from groundwater, and during the last 10 years the abstraction of groundwater has been around 600 million m3 of water per year. Groundwater is a limited resource and the energy consumption for the waterworks is considerable. Improved groundwater management can increase the exploitable groundwater, save energy, protect the groundwater from contamination, and ensure high water quality.

This study uses multi-objective optimization of an integrated well field model to improve the management of a waterworks. The integrated well field model called WELLNES (Well field Numerical Simulation Shell) has been developed; it simulates the hydraulic head in and around a groundwater well field. The well field model is a combination of a groundwater model, a well model, and a pipe network model. With this model it is possible to obtain good predictions of the groundwater level in the well field and of the pressure in the distribution pipes and thereby also good predictions of the energy used for abstracting the water.

Søndersø waterworks (northwest of Copenhagen, Denmark) is used as a case study. It abstracts 8 million m3 of water per year from 21 wells. West of the well field is a contaminated site, and it is important to avoid polluted water from entering the wells. During a 5 month simulation period the WELLNES model can predicts the energy consumption of the waterworks within 1.8% of the observed energy consumption.

Multi-objective optimization is performed to find the best way of operating the waterworks with respect to two objectives. The first is to minimize the risk of pollution from the contaminated site and the second is to minimize the energy consumption. The constraint is that the waterworks has to provide a given amount of water, and the control variables are the states of the pumps.

Three scenarios are performed. In the first scenario the objective is to improve the management of the waterworks given the current installation of the waterworks. The control variables are the states of the pumps, which can be either on or off. In the second scenario the objective is to search for additional improvements to the management by assuming that frequency regulators are installed on all pumps. The control variables are now the speeds of the pumps. The third scenario assumes new high capacity pumps and an increasing demand of water in the future. The objective is to investigate how this increased abstraction affects the energy consumption and water quality. The multi-objective optimization problems are solved by using genetic algorithms. Results from the three scenario optimizations will be presented and discussed.