Modelling Hydrological Consequenses on Groundwater Dependent Habitats

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Modelling hydrological consequenses on groundwater dependent habitats

Aalborg University

Introduction

A well field is planned 1 km north of a Danish river valley which is covered by a NATURA 2000 habitat area. Fens and springs in the area depend on stable groundwater flows and the well field potentially threatens the integrity of the habitats.

Hydrological modelling is potentially a very useful tool for studying how different abstraction scenarios affect the hydrology in the habitats. However it is necessary to describe groundwater, vadose zone and surface water flows on a small scale to capture the important flow processes. This is on the edge of how far we can go with distributed modelling today and requires a large amount of input, calibration and validation data.

In the presented work a solid data foundation for hydrological modelling was provided by intensively monitoring the natural hydrological conditions during a 3-year period and subsequently performing pumping tests and monitoring effects of pumping from the groundwater aquifer.

Hydrological modelling is shown to be a very useful tool for supporting decisions regarding groundwater abstraction in catchments that contain groundwater dependent nature.

Nested hydrological models

The model is a 3D distributed model describing saturated flow, unsaturated flow as well as surface runoff. A regional groundwater model is used to provide the boundary conditions for submodel 1 with a resolution of 25 X 25 meter and a detailed model for the fen area of 5 X 5 meter resolution.

The nested modelling approach is used to achieve a sufficient resolution and yet a manageable computational demand in the models.

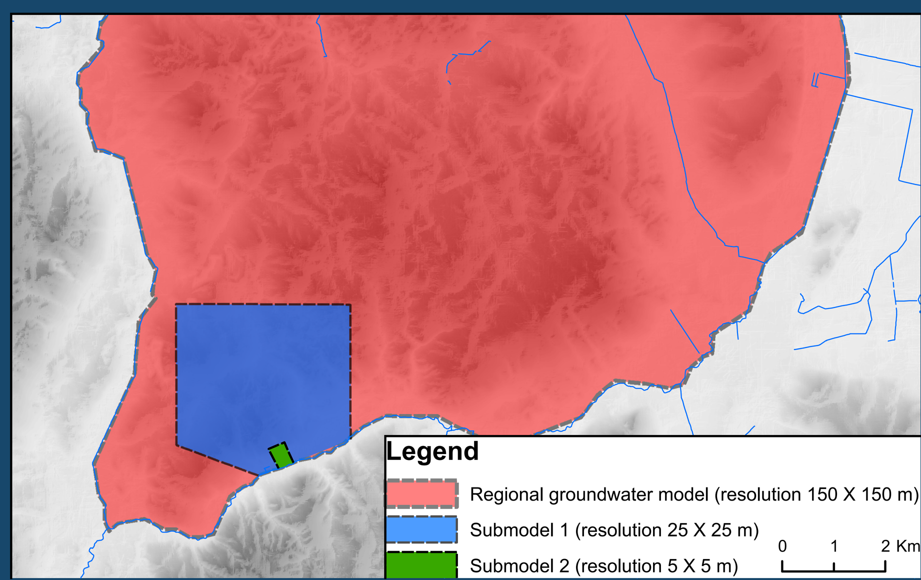


Figure 1: Boundary for the nested hydrological models

Small scale hydrology in fens

The rich fen area is located in a small depression in the terrain as illustrated in figure 2. Surface runoff in the fen ensures that flooding does not occur and the drainage ditches transport the water to the river. The model result is highly sensitive towards the detailed topography and the level of ditches and spring-overflows in the area. The 5 X 5 metre horizontal resolution is required to resolve these small scale structures in the numerical model.

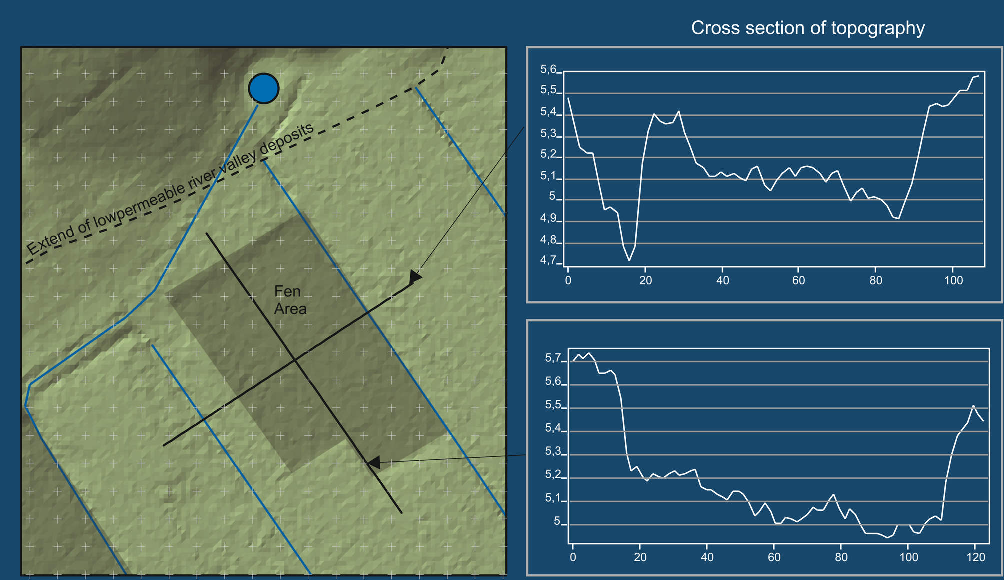


Figure 2: Illustration of the complex hydrological and topographical setting in the fen area

Modelling flow in natural springs

The flow in the springs play an important role in the ground-water surfacewater interaction in the rivervalley. Springflow is believed to be a result of cracks and highly conductive path-ways in the limestone aquifer. The actual structure and ex-tend of these pathways is unknown.

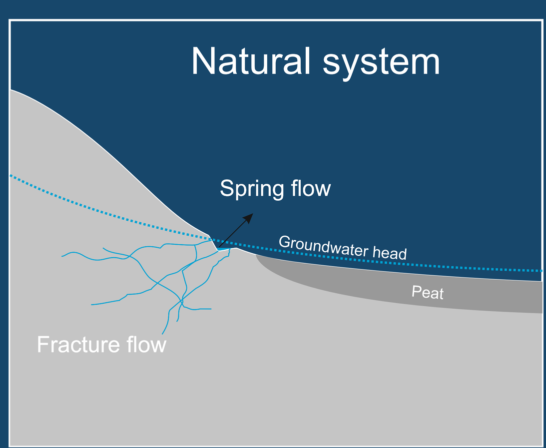


Figure 3: The perception of springflow in natural spings in study area

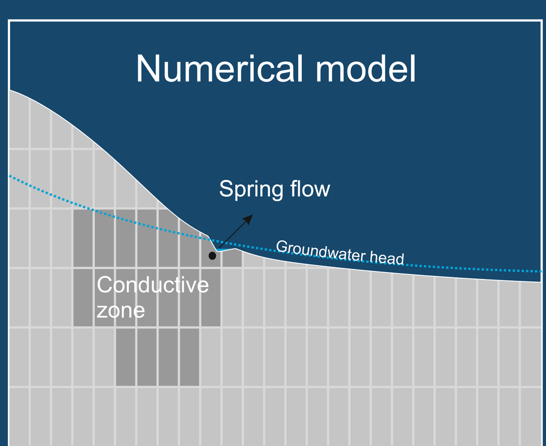
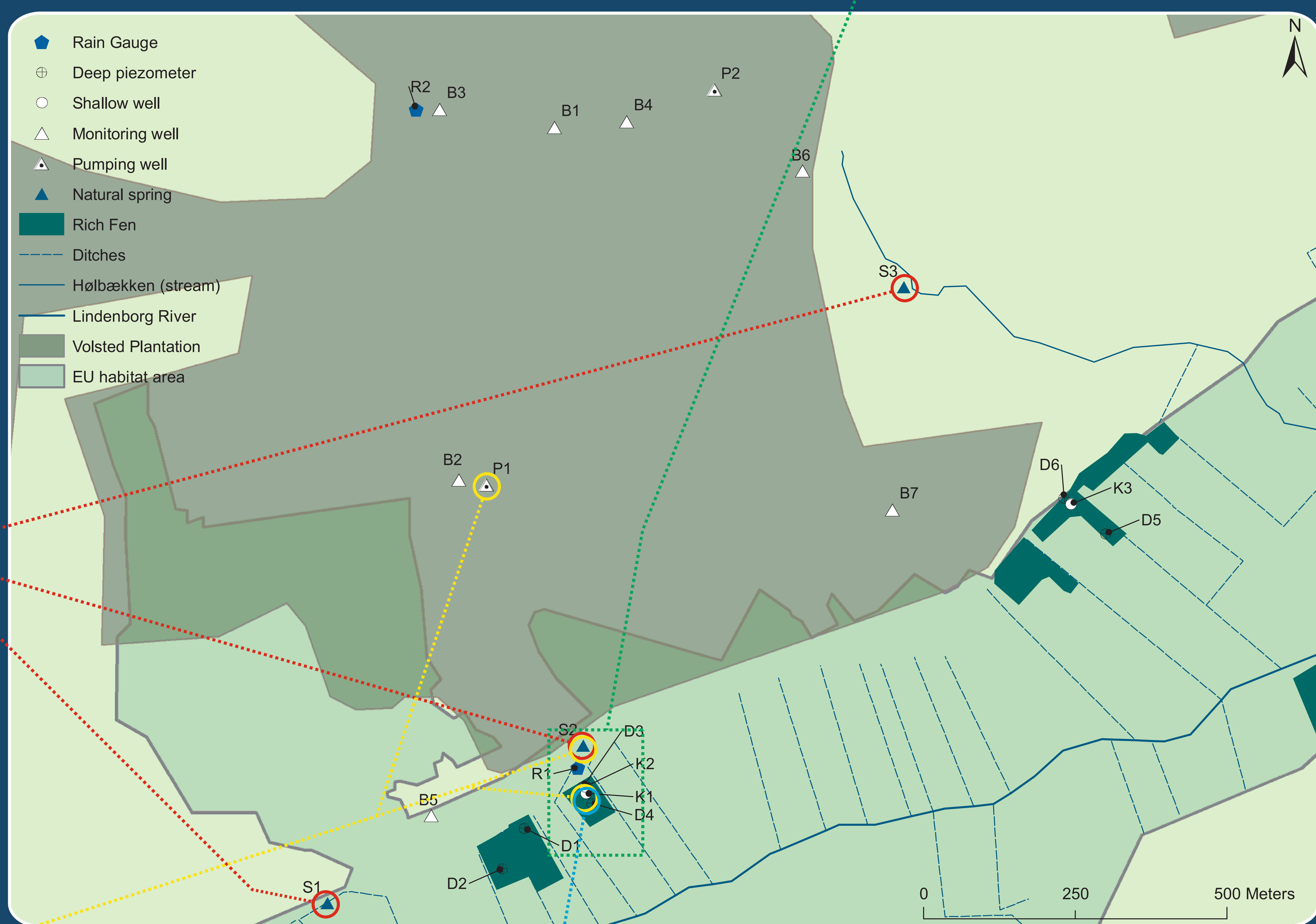


Figure 4: Principle of spring flow i the numerical model

In the numerical model a highly conductive zone con-nects the aquifer to a drain cell with a level correspon-ding to the water table in the spring. The leakage coeffi-cient in the drain cell is high allowing water to flow freely.



Model validation

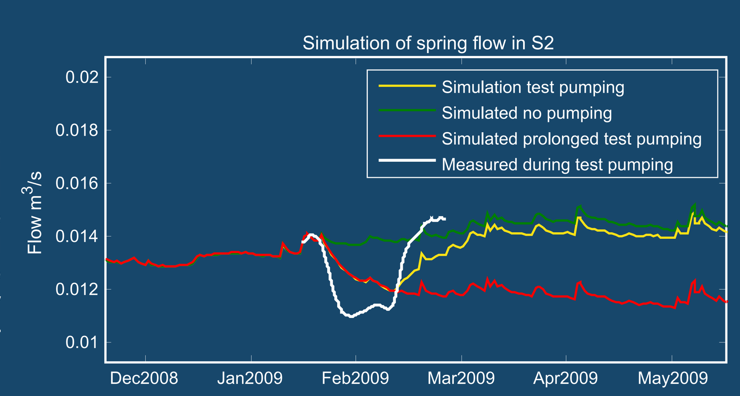


Figure 5:
Modelled and observed spring flow (S2) during pumping test i the well p1. The model response is slower than the actual response due to dual porosity in the limestone aquifer, but the simulated flow reduction matches the mea-surements

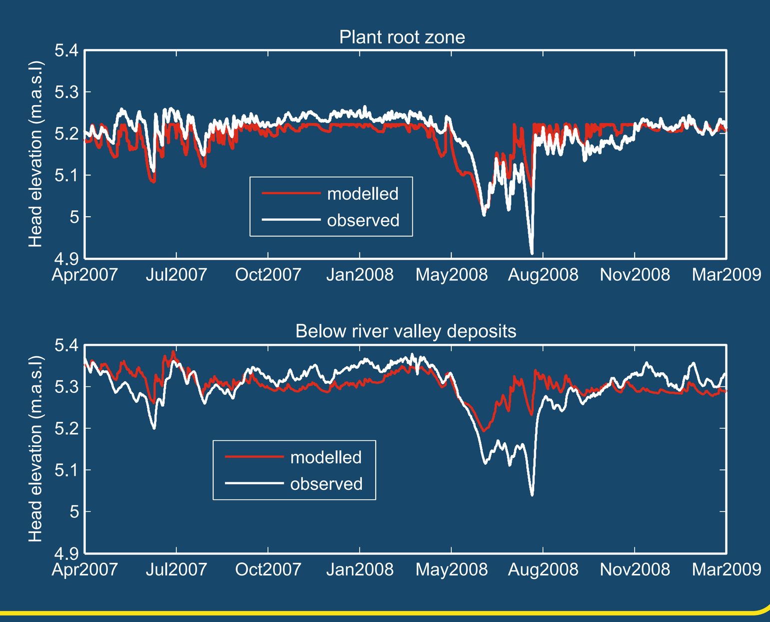


Figure 6:
Modelled and observed head elevation in a short (upper graph) and a deap (lower graph) piezometer in the fen area.
The model gives a good description of the water level fluctuations in the rootzone of the plants during both winter and summer periods.

Effect on head elevation and discharge through fens

The graphs illustrate the simulated impact on the fen from a realistic abstraction scenario starting on January 1st 2008. In dry periods during the summer the evapotrans-piration exeeds the ground-water discharge to the area and the water table drops as a part of the naturally occuring variations. The abstraction increases this drawdown by 3 cm (fig. 7).

During the winter season the watertable in the fen is not affected, but instead the groundwater discharge through the system is reduced by 10-25 % (fig. 8)

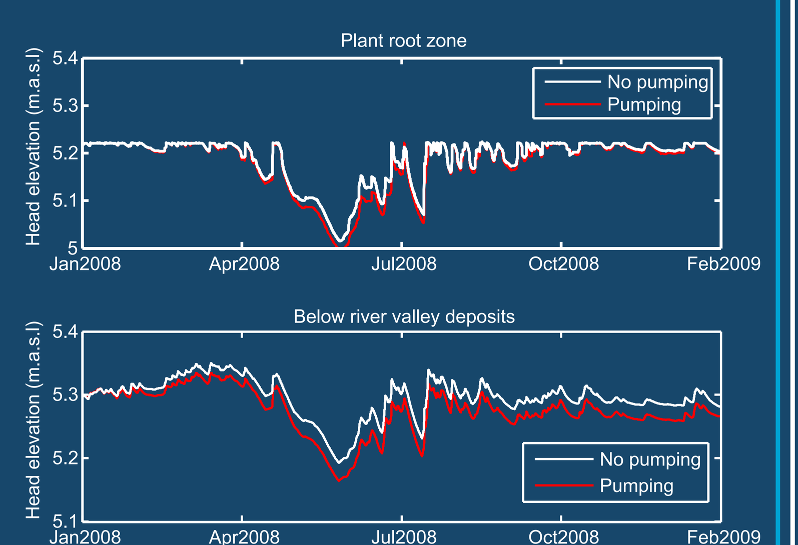


Figure 7: Change in head elevation due to pumping 1 mill. m³ pr. year from the plantation

Figure 8: Reduction in groundwater discharge to the fen area due to pumping of 1 mill. m³ pr. year from the plantation

Conclusion

The hydrological effect of groundwater abstraction on groundwater dependent habitats has been quantified by combining integrated numerical models at different scale. The model depends on a large amount of input data and observations used in calibration of parameters. The results can to some extend be validated and confirmed by measurements in the natural springs during pumping tests. In the fen areas no significant effect of pumping was measured and the reliability of the model depend on the ability to reproduce natural variations in the water level.

A scenario where 1 mill. m³ of water is abstracted from the plantation north of the river valley was simulated. The modelling results indicate that the water level in the rootzone of the fen will be lowered a few centimetres (fig. 7) during the summer period which is not considered critical. It is likely to be more important that the groundwater flow to the fen will be reduced between 10 % and 25 % according to the simulations (fig. 8).

Using hydrological modelling tools for prediction in groundwater dependent habitats gives not only the possibilities of conducting risk assessments and evaluating different abstraction scenarios, but it also contributes to the understanding of the hydrology that controls these areas. Potentially models are very useful in any habitat restoration project that involves changes to the hydrological regime however very large datasets are required.

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