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# Developing a methodology for identifying action zones to protect and manage groundwater well fields

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Implementation of a long term action plan to manage and protect well fields is a complex and very expensive process. In this context, the relevance and efficiency of such action plans on water quality should be evaluated. The objective of this study is to set up a methodology to identify relevant actions zones in which environmental changes may significantly impact the quantity or quality of pumped water.

In the Seine-et-Marne department (France), under French environmental laws three sectors integrating numerous well-field pumping in Champigny's limestone aquifer are considered as priority. This aquifer, located at south-east of Paris, supplies more than one million people with drinking water. Catchments areas of these abstractions are very large (2000 km2) and their intrinsic vulnerability was established by a simple parametric approach that does not permit to consider the complexity of hydrosystem. Consequently, a methodology based on a distributed modeling of the process of the aquifer was developed.

The basin is modeled using the hydrogeological model MODCOU, developed in MINES ParisTech since the 1980s. It simulates surface and groundwater flow in aquifer systems and allows to represent the local characteristics of the hydrosystem (aquifers communicating by leakage, rivers infiltration, supply from sinkholes and locally perched or dewatering aquifers). The model was calibrated by matching simulated river discharge hydrographs and piezometric heads with observed ones since the 1970s. Thanks to this modelling tool, a methodology based on the transfer of a theoretical tracer through the hydrosystem from the ground surface to the outlets was implemented to evaluate the spatial distribution of the contribution areas at contrasted, wet or dry recharge periods. The results show that the surface of areas contributing to supply most catchments is lower than 300 km2 and the major contributory zones are located along rivers. This finding illustrates the importance of rivers seepage for groundwater recharge.

In parallel, validation of the modelled hydrodynamic system was reinforced by implementing nitrogenous contamination simulations. This pollution is linked to intensive farming activities practised on the basin since the early 70's. This modelling was realized by coupling the hydrological model MODCOU and the agronomic model STICS allowing to generate the spatio-temporal evolution of sub-root nitrogen fluxes stemming from intensive farming. The evolution of nitrate concentrations observed and simulated in groundwater confirms the strong reactivity of the Champigny's aquifer to nitrogen fluxes entering the system.

For the contributory zones, the calculated transfer time between these areas and catchments shows very short transfer times in stream infiltration sectors (less than 2 years), and longer transfer times (up to 10 years) from layers partially occupied by an upper aquifer existing in the overlying formation of Brie's limestones.

The relationship between the main recharge areas and transfer times, between these areas and a specific well field, allows to determine relevant priority action areas. Action plans of such protected areas should be applied to manage long term changes represented by an evolution of the polluting fluxes that result from land use change or evolution in the recharge conditions of hydrosystem.