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A new quasi-3D unsaturated–saturated hydrogeologic model of the Plateau de Saclay (France)

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SUMMARY

A new hydrogeologic model is developed for the Plateau de Saclay (20 km south-west of Paris, France), which covers an area of 74 km^2. It is based on a 2D model of the Fontainebleau Sands aquifer, combined with a 1D model of the unsaturated zone, taking into account the spatial variability of the groundwater permeability field and the thickness of the unsaturated zone. The paper focuses on the estimation of a triplet of parameters (permeability, infiltration and effective porosity), based on transient flow simulations. First, the permeability is obtained by inversion of mean hydraulic head data for different values of infiltration. Then, infiltration and effective porosity are determined by using transient flow simulations and fitting the hydraulic head measurements at several piezometers over the 1970–2014 period. The infiltration is estimated at between 125 and 150 mm/yr, the mean permeability between $2 \cdot 10^{-5}$ and $6 \cdot 10^{-5}$ m/s, and the effective porosity between 20% and 30%. Furthermore, the role of the unsaturated zone is quantified and the induced delay is estimated at about 20 years in the case of the transport of a tracer.

1. Introduction

The estimation of infiltration, permeability and effective porosity is a necessary prerequisite for developing a hydrogeologic model. These three parameters are of crucial importance when estimating the transport of effluents, that is to say, their transport velocity and spatial concentration.

Unfortunately, these parameters are spatially variable and difficult to estimate. The amount of infiltrated water, or recharge, is the part of the rainfall that moves through the unsaturated zone, after evaporation from moist soils, transpiration of plants and runoff. It is classically obtained from a hydrological budget (Thornthwaite and Mather, 1955), using rainfall measurements, potential evapotranspiration calculations and parameters such as soil moisture capacity and runoff, which are also difficult to estimate.

The permeabilities are obtained locally by pumping tests and at larger scales by inversion of hydraulic head data (de Marsily et al., 2000), while the final permeability field depends on the estimated infiltration.

The effective porosity is also called kinematic porosity, and corresponds to that part of the total porosity of a porous medium where the water can circulate and thus contribute to fluid flow. It can be estimated from pumping tests (Cooper and Jacob, 1946; Boulton, 1963) or by means of drift and pumpback tracer tests (Hall et al., 1991), but with large uncertainties due to the difficulty of interpret the tests.

If hydraulic head measurements are sufficiently numerous and if the time period is sufficiently long, the effective porosity can be fitted by using transient flow simulations and comparing measured and calculated hydraulic heads. In this case, infiltration, permeability and effective porosity are strongly linked, since a change of one of these parameters will lead to a change of the other two.

The approach described here comes under the scope of a new hydrogeologic model of the Plateau de Saclay, which is located about 20 km south-west of Paris (France), and is being developed to meet the requirements of the CEA-Saclay research centre, located on the southern part of the Plateau de Saclay.

As with any factory, the CEA-Saclay research centre has to submit regulatory documentation concerning their discharges of liquid effluents. This task includes the ability to estimate the transport of effluents in the event of accidents. In this context, the construction of a precise hydrogeologic model is of primary importance.

The hydrology and hydrogeology of the Plateau de Saclay have been widely investigated, mostly in the framework of studies for the CEA-Saclay research centre. Recently, numerous studies have been undertaken as part of the new development project of the

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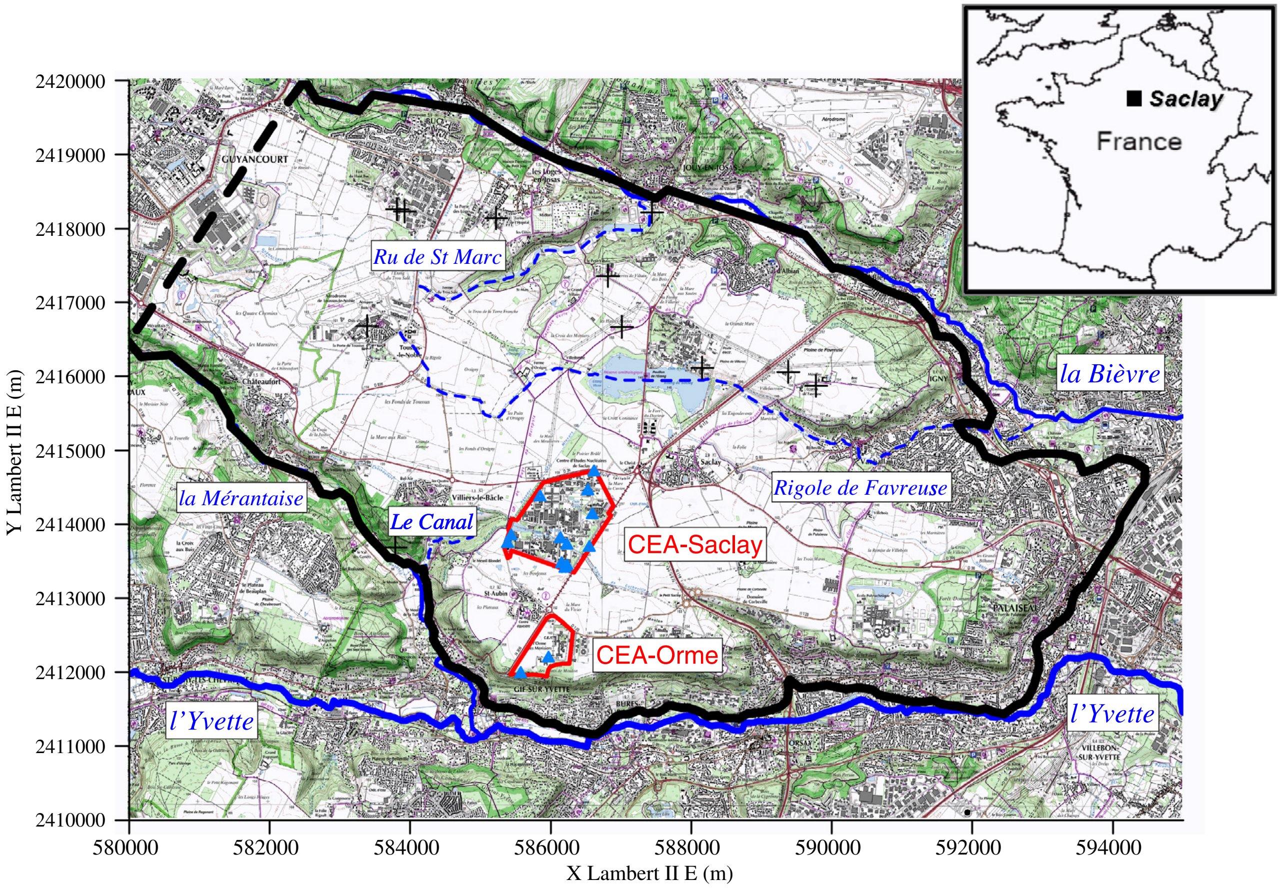

Fig. 1. Domain of interest, CEA-Saclay and CEA-Orme sites, with main rivers and streams on IGN 1:25,000 topographic map. The dashed line on the north-west boundary is associated with the zero flux condition. The boundary shown as a solid line is associated with the fixed hydraulic head condition. Triangles and vertical crosses indicate CEA and BRGM observation points for hydraulic head.

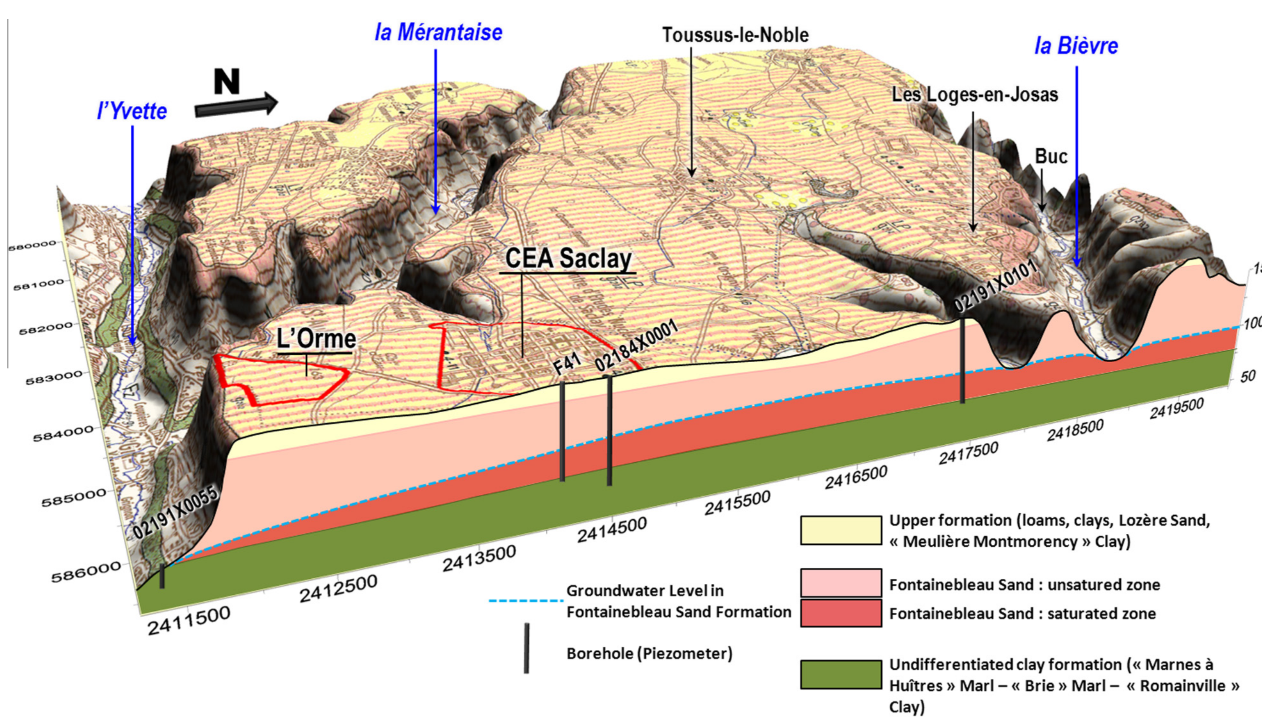

Fig. 2. North–south cross-section showing the two main aquifer formations, the mean hydraulic head, the main localities and some wells. The vertical scale is exaggerated by a factor 100. The topographic surface represents the geological map (Pomerol, 1975).