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2D numerical modelling of tracer transport and dilution in the Loire river

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Abstract:

A TELEMAC-2D numerical model of a 50 km Loire river section has been constructed. The aim of the model is to study the downstream transport and dilution of a Nuclear Power Plant (NPP) liquid emissions. It focuses on situations from low-water to mean flow rate and thus the flood plain is not taken into account. The model is based on recent bathymetric and validation data: bottom topography, water levels, current velocities and tracer concentrations have been collected during field campaigns carried on 2014. The numerical model is based on the latest V7P0 version of Telemac-2D. Forcings of the numerical model are Loire flow rate, NPP water intake and NPP water and tracer release.

First step is simulation of several stationary situations, corresponding to different flow rates. Thus, a preliminary model calibration (based on Strickler's law) is achieved, as well as sensitivity studies (time-step, mesh size). Calibration of low-level flow is the more complex.

A field campaign, corresponding to a flow rate slightly greater than mean flow rate, has been carried out: water levels and flow currents have been measured. This situation is simulated: a finer model calibration is realised by using water level data. Model validation is achieved by comparing simulated velocities and ADCP (Acoustic Doppler Current Profiler) current data. This comparison shows the capability of the numerical model to reproduce quite well hydrodynamics in the whole study domain. Nevertheless, differences between numerical and experimental data are locally observed but can obviously be related to uncertainties of bottom representation in the model mesh.

The NPP liquid emissions transport and dilution study is based on two simulations. For these two situations, field campaigns have been achieved: a conservative and non buoyant tracer has been released by the NPP and its concentration has been measured from NPP to 30 kilometres downstream. The first situation corresponds to a mean river flow rate. The modelling results are in good agreement with field data and show the ability of the numerical model to reproduce transport and dilution in this flow range (fig. 1). Only two measured profiles show significant differences with measurements. These difficulties are not related with tracer quantification but rather with plume position and width. The low-level situation is more complex, especially within the first 5 kilometres downstream of the NPP. Plume geometry reproduction (width, position) is the main difficulty whereas downstream evolution of maximum tracer concentration is quite well represented (fig. 2). Beyond the 5 kilometres area, the plume is again rather well represented (excepting a little zone located at 12 kilometres from NPP). A moderate overestimation of lateral mixing is possibly observed but this is not problematic for model applications.

Thus, modelling difficulties are localized (from NPP to 5 km downstream and in a little area at 12 km from NPP) and especially encountered when water levels are low. The problematic zone is characterised by many sand banks separated by narrow and shallow (until 20 – 30 cm water depth when river discharge is low) channels (braided river bed) (fig. 3). In these conditions, the

flow and consequently the plume position are extremely sensitive to bathymetry; this sensitivity increases significantly when water depths decrease. Thus, modelling difficulties are doubtless due to uncertainties of bottom representation in the model mesh. Indeed, in this area, bottom data has been interpolated from bathymetric profiles separated by 200 to 300 m; data resolution does not allow a sufficiently accurate river bed representation in the model mesh with regards to the complexity of this zone. In the other areas, morphology of the river bed is less complex and water depths are more important even in low-level situations; the modelling results are thus of better quality. In order to improve modelling, a new bathymetric campaign with a higher resolution measurement technique (multibeam technique) should be realised in complex identified areas. Further work is already planned in order to estimate more precisely sensitivity of the model results in some areas of special interest to bathymetric realistic evolutions.

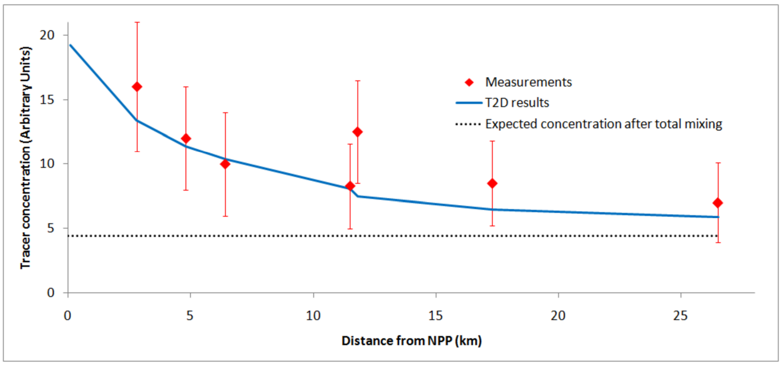

Figure 1 – Downstream evolution of the tracer concentration for mean flow rate situation.

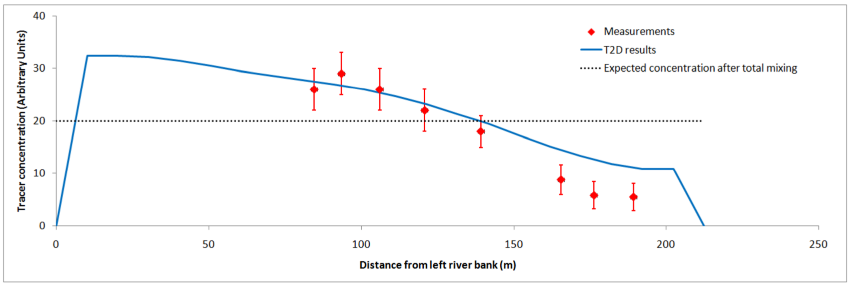

Figure 2 – Example of concentration cross-section profile for low level situation.

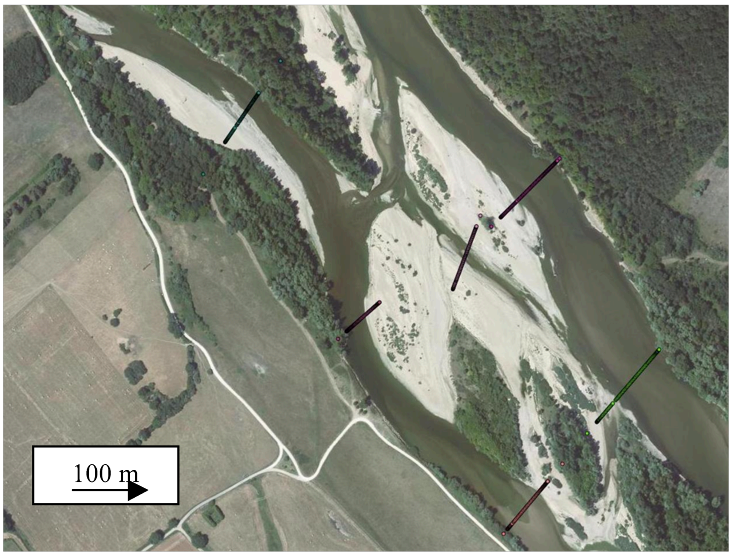

Figure 3- Example of complex river bed morphology encountered in the studied zone (position of the bathymetric data profiles is indicated).