A simplified 1D modelling to simulate the Middle Loire River bed evolution

Approches de simplification pour une modélisation unidimensionnelle des évolutions du lit de la Loire moyenne

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RÉSUMÉ

Au cours de ces derniers siècles, les systèmes fluviaux, influencés par les actions anthropiques, se sont considérablement modifiés. La modélisation des évolutions des lits alluviaux à grande échelle de temps et d'espace nécessite une simplification des données afin de réduire le temps de calcul. Des simplifications géométriques et hydrologiques sont ici testées dans un modèle de transport solide unidimensionnel (RubarBE) afin d'être comparées aux résultats obtenus avec la géométrie détaillée et la chronique de débit complète. La géométrie simplifiée permet une modélisation des évolutions du lit pertinente tout en réduisant le temps de calcul; la simplification des chroniques de débit illustre la sensibilité des modèles numériques hydro-sédimentaires à l'hydrologie. Enfin l'application des simplifications sur l'ensemble de la Loire moyenne sur la période 1996-2006 confirme les tendances observées par l'analyse des données.

ABSTRACT

Over the past two hundred years, river dynamic has been significantly affected by human disturbances. Associated channel changes may impact infrastructures located along the river. New tools are therefore required to predict river bed evolution of long river reach over several decades. The proposed methodology is conducted to reduce the calculation time of 1D morphodynamic models. Simplifications of the geometry and hydrology are proposed and compared to a detailed 1D model (RubarBE). The simplified geometry allows pertinent calculation of the river bed evolution whilst reducing calculation time. The use of simplified hydrographs highlights the sensitivity of sediment transport modelling to hydrology. Finally the application of the simplifications to the whole Middle Loire River confirms the general trend observed between 1996 and 2006.

KEYWORDS

1D model, large scale, Middle Loire River, river bed evolution.

INTRODUCTION

Over the past two hundred years, river dynamic has been significantly affected by human disturbances. The associated channel changes may impact infrastructures located along the river. As modelling river bed evolution of long river reach over several decades requires long calculation time, a methodology is presented to reduce the calculation time of 1D morphodynamic model. The approach has been developed and implemented on a 450 km long reach of the Middle Loire River (France).

1 DERIVATION OF SIMPLIFIED GEOMETRY AND HYDROLOGY

1.1 Definition of a simplified geometry

The study reach is divided into homogeneous reaches; homogeneity is based on parameters relevant for sediment transport: topography, sediment characteristics of the bed, water and sediment inputs, singularities (dams, weirs, confluence, etc). Each reach is then characterized by two simplified cross sections defining its slope. The shape of the cross section is based on the assumption that for any discharge, the water elevation calculated in the simplified geometry should be as close as possible to the initial water elevation.

The methodology has first been derived and validated on a 30 km reach of the Middle-Loire River. The river hydraulics and bed evolution of the reach are simulated with RubarBE, a one-dimensional morphodynamic model (Paquier, 2009). The water elevations calculated with the hydraulic model on existing geometry are then used to derive simplified cross sections. The geometry of existing singularities (bridge, weir) is excluded from the simplification and added in the model as transitional cross-section. An example of the simplified cross sections obtained for a reach is illustrated on figure 1a.

1.2 Definition of a simplified hydrology

Different approaches were tested to simplify the measured hydrographs. Calculations reveal the importance of the rising and falling limb of a flood event on the resulting modelled bed evolution; the approach consisting in a succession of steady discharges was therefore invalidated. A succession of peaks punctuated by constant discharges was then tested. A critical discharge is thus defined, under which sediment transport is assumed to be negligible in terms of river bed deformation. Figure 1b presents the simplified hydrograph obtained for two years of discharge measurements.

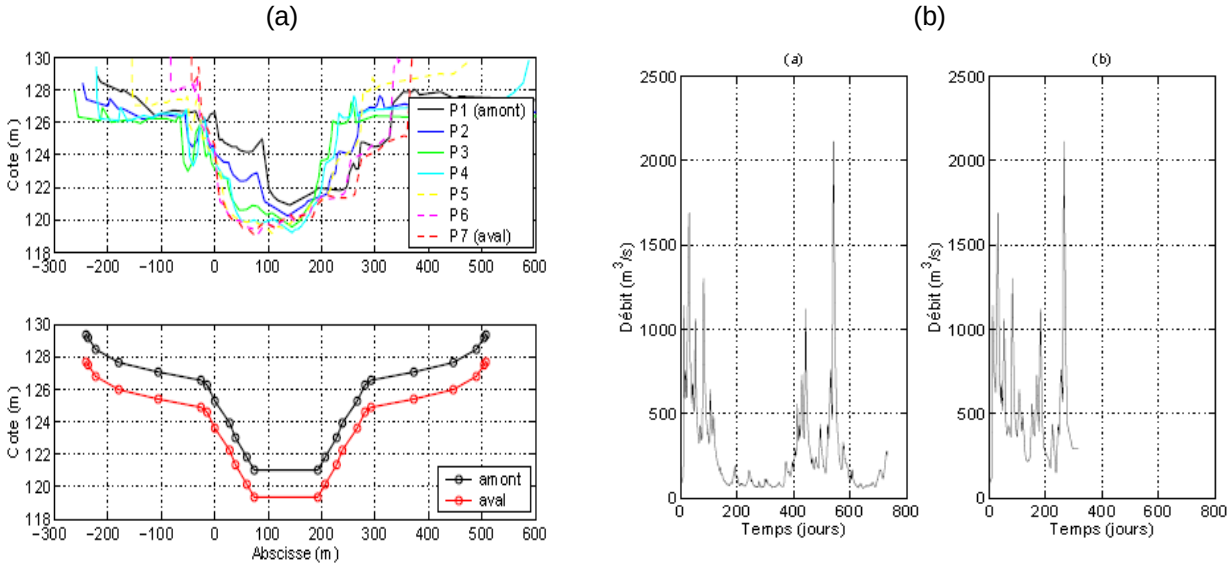

Figure 1 : (a) Simplified geometry and (b) simplified hydrology of a two year hydrograph (1996-1998)

2 APPLICATION AND RESULTS

2.1 Tests on reference sites

A comparison is provided between measured data and simplified model. The methodology is derived and tested on an anthropogenised site (Belleville) prior to being validated on two other references sites where channel patterns differ (anabranched and meandering sections) and the amount of data is sufficient for validation. The volume deposited or eroded is calculated for each reach (Fig. 2); the results obtained with the simplified approach slightly overestimate bed aggradations and degradations (+10% in average). In particular the upstream and downstream reaches of the reference site considered present an overestimation of evolution. Overall, the results obtained with the measured data and the model using the simplified geometry and hydrology present very similar trend of bed adjustments.

2.2 Application to the Middle Loire River

The simplified geometry and hydrology were then applied to the whole Middle Loire River to simulate river bed evolution between 1996 and 2006. The general trend of bed adjustment obtained with the simplified model compares well with the observed data although some significant differences might be observed locally. The results obtained on the reference site of Belleville were then extracted from the whole model and compared to the results obtained for the reference site (Fig. 2). The incision obtained on the first reach with the simplified local model was associated to the boundary condition as the simplified whole model does not show this evolution.

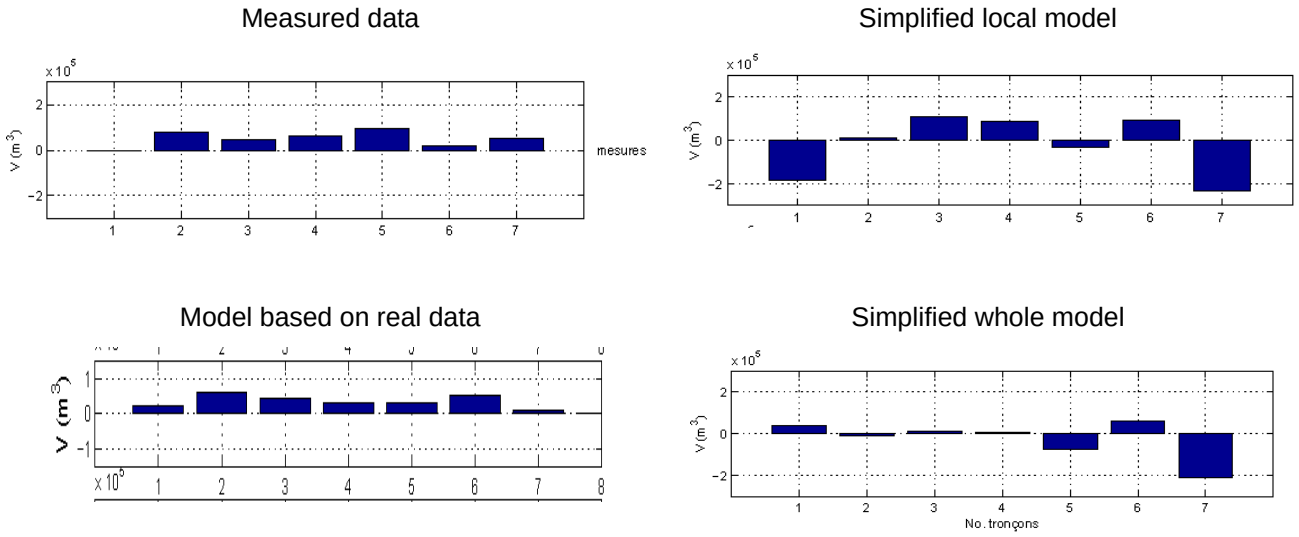

Figure 2 : Comparison of the volume deposited or eroded on the reaches defined on the reference site of Belleville (local model refers to the 30 km long model reach and whole model to the whole Middle Loire model)

CONCLUSIONS

The simplified geometry allows pertinent calculation of the river bed evolution whilst reducing calculation time. The use of simplified hydrographs highlights the sensitivity of sediment transport modeling to hydrology. Finally the application of the simplifications to the whole Middle Loire River confirms the general trend observed between 1996 and 2006.

LIST OF REFERENCES

Mosselman E. (2005). *Basic equations for sediment transport in CFD for fluvial morphodynamics.* Chapetr 4 in : Computational Fluid Dynamics; applications in environmental hydraulics, Eds. P.D. Bates, S.N. Lane & R.I. Ferguson, Wiley pp 71-89.

Paquier A. (2009). *Notice d'emploi de RubarBE (version d'Octobre 2009).* Rapport Technique, Cemagref.