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Numerical Modeling in Flood Risk Assessment: UK Case Study

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Abbreviations: (CES): Conveyance Estimation System; (DCM): Divided Channel Method; (HEC-RAS): Hydrological Engineering Centre River Analysis System; (SCM): Single Channel Method

Introduction

River flooding is one of the greatest natural threats to mankind, causing human fatalities, displacement of people and economic losses. In addition to economic and social damage, floods may have severe environmental consequences. In 2007, Britain faced a summer of devastated storms, with thousands of homes and businesses under water, and thirteen fatalities. Although the UK Government has hugely invested in outstanding research and defenses to overcome this problem, the 2015 winter floods on Cumbria seemed to indicate that nothing has changed.

Some of the reasons for increasing flood scenarios are out of the Civil Engineers' scope. Climate change as well as in appropriate river management and land use in flood plains are raising the flood risk and vulnerability [1]. These are external actions we have to take into account and civil engineers do not have the key to change them. However we have the knowledge to predict how rainfall is going to affect buildings and infra structures (such as roads, railways, etc.) and what actions must be put in place to reduce flood risk. The understanding of the behavior of rivers during flood periods in order to accurately predict water levels is essential for the design of flood alleviation works. There are numerous methods and approaches that have been employed in recent times to facilitate accurate estimation and prediction of discharge, conveyance and water surface level of rivers during over bank flow.

The UK Environment Agency has developed several reports in order to reduce uncertainty in flood level estimation [2] and to improve understating of numerical modeling in rivers (SC120002/R Technical report on latest benchmarking results and SC080035/SR Technical report on theoretical basis). However a gap in the knowledge about how 1D/2D numerical models estimate water levels and velocities during overbank flow is still remaining. The aim of this paper is to summarize the application of quasi two dimensional Conveyance Estimation System (CES), developed by the UK Environment Agency, and compare the results to that of the traditional 1D methods, Single Channel Method (SCM) and Divided Channel Method (DCM) using Hydrological Engineering Centre River Analysis System (HEC-RAS) software. The two-dimensional SRH-2D [3] model is also used for comparison of water levels and velocity distributions. A great effort has been made over the last decades to improve calculation of water levels and velocities in real rivers by the use of 2D and 3D modeling. However some important uncertainties are still unsolved. In this context, an accurate 1D model easy to calibrate and with the support of the CES is proposed as an improved tool for comparison.

Methodology

One dimensional hydraulic model has been successfully used during years for flood simulation in rivers. However, during the last 20 years the extensive development in computational capacity has increase the research and practical use of two dimensional modeling. In this research the use of both 1D and 2D modeling is proposed. The 1D HEC-RAS simulation model [3] and the CES model (Environment Agency, 2004), are compared with the 2D SRH-2D model by the U.S. Bureau of Reclamation [4] in terms of water levels, velocity distributions and flood extension. For unsteady flow, HEC-RAS solves the full, dynamic, 1D Saint Venant Equation using an implicit, finite difference method. The SRH-2D solves the 2D dynamic wave equations, i.e., the depth averaged St. Venant equations with the finite volume numerical method. The Environment Agency's CES model is based on the LDM [5,6] and it combines the continuity and momentum depth averaged equations of motion for steady conditions and in the stream wise component. The general equation of the model for a straight river (sinuosity equal 1.0) is obtained.

The simulation of the study reach of river Main (UK´s Northern Ireland) on both CES and HEC-RAS computational modeling software and the two dimensional code SRH2D have been calibrated with the field data [7,2]. The three codes have been applied by using the same boundary conditions, cross section data and flow parameters in order to have the same criteria for comparison and validation. Finally the water surface level and velocity distribution results obtained from these codes were analyzed and compared with the available field data to validate and verify the results. Figure 1 shows a full graphical description of river Main geometry and study length.

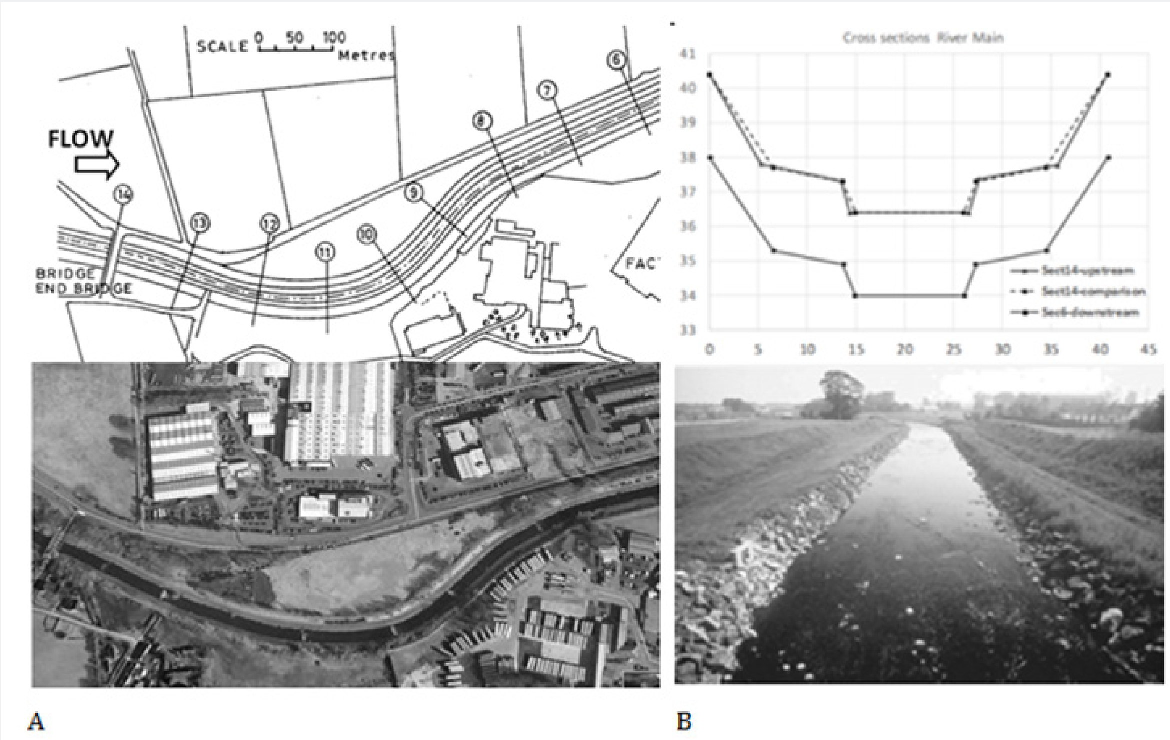

Figure 1:

a. River Main plan view (left). Location of cross-sections from upstream (s14) to downstream (s6).

b. River Main cross section view (right). Cross sections, numbers 14 and 6 respectively.

Results and Conclusion

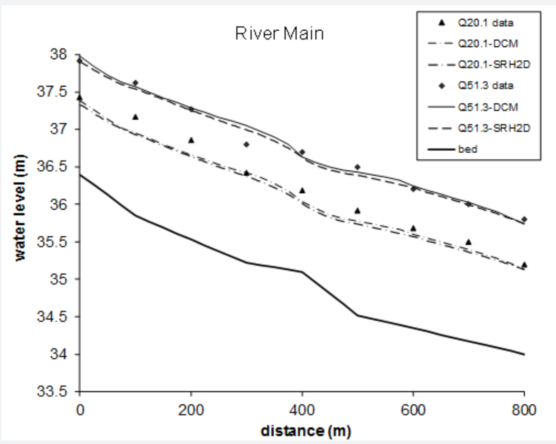

Figure 2: Water level field data and 2D computed water surface (W.S.) compared with 1D water surface (DCM) for two different overbank discharges, Q51.3 and Q20.1.

The water levels obtained with HEC-RAS and SRH2D for the two overbank discharges (20.1 and 51.3 m3/s) are shown in Figure 2 HEC-RAS use two different methods for the calculation of water levels. The bank stations are located on the top of the main channel (DCM) or on the top of the flood plain walls (SCM) and two separated solutions are obtained. Only the DCM solution is shown here as the DCM gives lower water levels than the SCM for the same discharge. The results obtained with SRH2D model are shown in the same Figure. The water level profiles obtained with 2D modeling (turbulence model) are lower than those obtained with the DCM for all the discharges. The Manning's coefficients are the same in both models, as well as the boundary conditions.

However, 2D modeling has some advantages over 1D modeling. First, the changes in main channel and floodplain sinuosity are taken into account; second, it considers internal energy losses due to flow turbulence; and third, consequently the velocity direction and distribution is better simulated. In Figure

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3 the velocity distribution obtained with 1D [8] (DCM) and 2D models are compared with field measurements. The velocities given by SRH2D improve slightly the velocities obtained with DCM. In order to improve 1D modeling, the results obtained with CES are discussed [9]. The first step is that for straight river channels with moderate roughened flood plains, the water profiles obtained with1D model are better than with the 2D model. However, the distribution of depth averaged velocity can be obviously improved. The CES is applied to section 14 (Figure 3), using the same bed slope and Manning's coefficient of roughness than in 1D modeling. Figure 3 shows that the velocity distribution obtained with CES fits better with the data than the distribution given by 2D model.

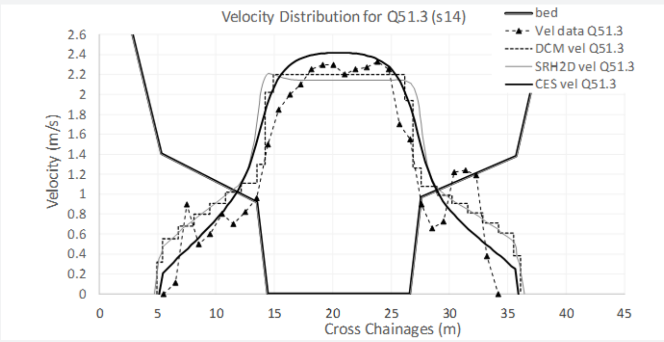

Figure 3: Velocities of field data (Martin and Myers, 1991) and computed with 1D (DCM), 2D (SRH) and CES for over-bank discharge Q51.3.

This study illustrates some of the problems that affect common 1D numerical models in reproducing overbank flow. 1D models are not able to yield an accurate velocity distribution across the section of a straight compound channel. Secondly, the comparison between the field data and the SRH2D model shows the need to take into account that the Manning's coefficients valid for 1D modeling are not accurate enough for 2D simulations. Therefore, some uncertainties rising from the use of 2D models can provide uncertain results respect to better predictable estimations obtained by 1D modeling. The prediction of accurate water levels and velocity distributions in overbank flows is a major challenge in numerical modeling. Typical 2D finite volume codes based on turbulence model trend to under predict main channel and flood plain interaction. These 2D models slightly improve the depth-averaged velocities obtained with 1D model for the straight river case analyzed here in. In order to better simulate velocities, the CES based on Lateral Distribution Method is proposed for comparison. The CES gives a better representation of momentum interaction between main channel and flood plains and of the velocity distribution across the section. This methodology has been contrasted with field river data under gradually varied conditions, confirming the results of some previously published works on the topic under different conditions [10].

References

1. Kundzewicz ZW, Kanae S, Seneviratne SI, Handmer J, Nicholls N, et al. (2014) Flood risk and climate change: global and regional perspectives Hydrological Sciences Journal 59:1 1-28.
2. DEFRA Environment Agency (2003) Reducing uncertainty in river flood conveyance, Interim report 2 Review of methods for Estimating Conveyance. Project W5A-057 HR Wallingford UK.
3. US Army Corps of Engineers (2008) HEC-RAS, Hydraulic Reference Manual. Hydrologic Engineering Center Davis Version 4.0.
4. Lai YG (2008) Theory and user manual for SRH-2D. Denver, Bureau of Reclamation Colorado: USA.
5. Wark JB, Samuels PC, Ervine DA (1990) A practical method of estimating velocity and discharge in compound channels. Proc River Flood Hydraulics, pp. 163-172.
6. Shiono K, Knight DW (1991) Turbulent open channel flows with variable depth across the channel." J Fluid Mechanics, pp. 617-646.
7. Martin LA and Myers WRC (1991) Measurement of overbank flow in a compound river channel. Proc ICE Water Maritime and Energy 2, pp. 645-657.
8. Mc Gahey C, Samuels PG, Knight DW (2006) A practical approach to estimating the flow capacity of rivers application and analysis. Proc River Flow Lisbon 1: 303-312.
9. EEA (2011) Mapping the impacts of natural hazards and technological accidents in Europe an overview of the last decade. EEA Technical Report. European Environment Agency Copenhagen, Denmark.
10. Vionnet C, Tassi P, Martínv Vide, JP (2004) Estimates of flow resistance and eddy-viscosity coefficients for 2D modelling on vegetated floodplains. Hydrological processes 18(15): 2907-2926.

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