MATHEMATICAL MODELING OF THE MORPHODYNAMIC ASPECTS OF THE 1996 FLOOD IN THE HA! HA! RIVER

RUI M. L. FERREIRA[1], JOÃO G. A. B. LEAL[2] and ANTÓNIO. H. CARDOSO[3]

[1] Teaching Assistant, Department of Civil Engineering & Architecture,
Instituto Superior Técnico, Av. Rovisco Pais, Lisboa, 1049-001, Portugal
(Tel: +00-351-218418155, e-mail: ruif@civil.ist.utl.pt)
[2] Teaching Assistant, Department of Civil & Architecture,
University of Beira Interior, Calcada Fonte do Lameiro, 6201-001, Covilha, Portugal.
(Tel: +351-275329996, Fax: +351-275329969, e-mail: jleal@ubi.pt)
[3] Professor, Department of Civil Engineering & Architecture,
Instituto Superior Técnico, Av. Rovisco Pais, Lisboa, 1049-001, Portugal
(Tel: +00-351-218418154, e-mail: ahc@civil.ist.utl.pt)

Severe rainstorms scourged the Saguenay region, south Québec, Canada, between the 18th and the 21st of July 1996. Due to the overtopping and sequent failure of an earthfill dyke, River Ha! Ha! experienced a significative increase in the peak flood discharge. The dam-break wave, superimposed to the natural flood, provoked massive geomorphic impacts in the downstream valley (Lapointe *et al.* 1998, Brooks & Lawrence 1999, Capart *et al.* 2003).

As seen in Fig. 1, the morphologic impacts comprised the carving of a new channel in the forest floor downstream the "Cut-away" dyke (photo A), important aggradation at the low-slope reaches such as "Eaux-mortes" (photo C), massive inception at "Chute á Perron" (photo B) and at other convex profiles and general bed widening due to bank erosion.

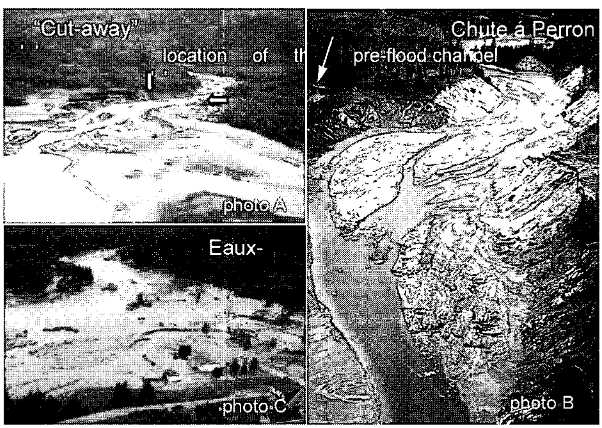

Fig. 1 Post-flood images of reaches of River Ha! Ha!. Photo A: location of the "Cut-away" dyke. White arrows point to the encounters of the eroded dyke. Photo B: "Chute á Perron"; white arrow shows the location of the old channel. Photo C: aggradation downstream of "Chute á Perron". Photos A and C from the Earth Sciences Information Centre, Natural Resources Canada; photo B from Brooks & Lawrence (1999).

The objective of this work is to discuss the mutual influence of the morphdynamic and hydrodynamic aspects of the flood. In particular, it is discussed how the morphologic evolution of the river, for instance the migration of its knickpoints, dictates the occurrence of supercritical flow reaches and hydraulic jumps. The discussion is based on a one-dimensional simulation of the hydro- and morphodynamic aspects of the flood. The simulation of this extreme flood event represents a highly demanding computational test because: i) the morphologic impacts were unusually pronounced, ii) subcritical and supercritical flow regimes may co-exist in the computational domain at a given time and iii) flow singularities such as hydraulic jumps or critical flow points can be created and destroyed during the simulation.

The conceptual model is valid for non-prismatic, non-rectangular channels whose banks are susceptible to be eroded. It is a capacity model based on shallow-flow conservation equations. The closure formulæ and the bank erosion model are those presented in Ferreira 2005, pp. 447-475. Although the qualitative results are satisfactory, it is clear that erosion is not as well reproduced as deposition (Fig. 2). The model is able to find non-oscillatory solutions even when subjected to important lateral sediment input. Artificial viscosity is at the root of this robust behaviour.

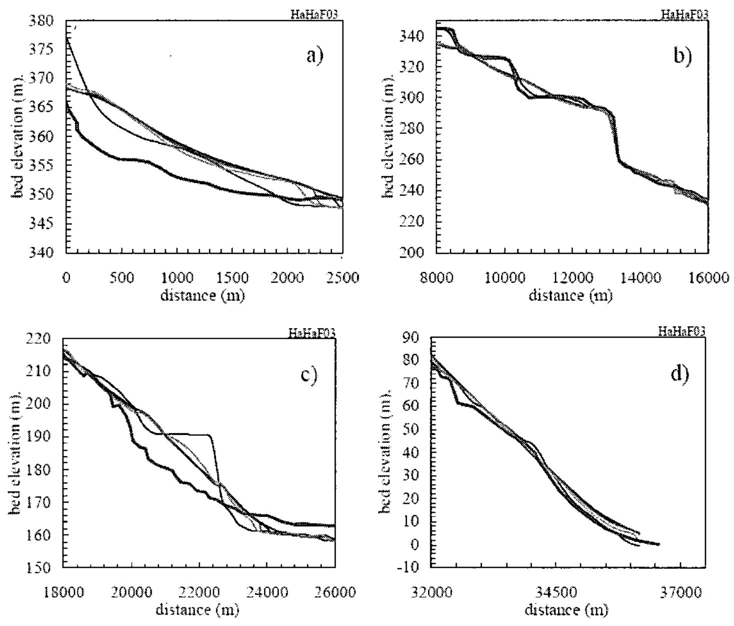

Fig. 2 Morphologic evolution of the River Ha! Ha!. Black line (——) stands for the initial bed profile; green line (▬) stands for the field data expressing the final bed profile. Computed profiles at t = 26 h (——), t = 32 h (——), t = 40 h (——) and t = 67.5 h (——).

One of the most accomplished characteristics of the model is its ability to deal with different flow regimes within the computational domain. In addition, it is shown that the model withstands the elimination of flow structures such as hydraulic jumps, as a result of profound morphologic changes, without disturbing the solution. The model for the elimination of supercritical reaches is presented and discussed.

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