Systematic flood modelling to support flood-proof urban design

Martin Bruwier[1], Ahmed Mustafa[2,3], Daniel Aliaga[3], Pierre Archambeau[1], Sébastien Erpicum[1], Gen Nishida[3], Xiaowei Zhang[3], Michel Pirotton[1], Jacques Teller[2] and Benjamin Dewals[1]

[1]University of Liège, Urban and Environmental Engineering, HECE, Liège, Belgium
[2]University of Liège, Urban and Environmental Engineering, LEMA, Liège, Belgium
[3]Computer Science Department, Purdue University, USA

Context and Objectives

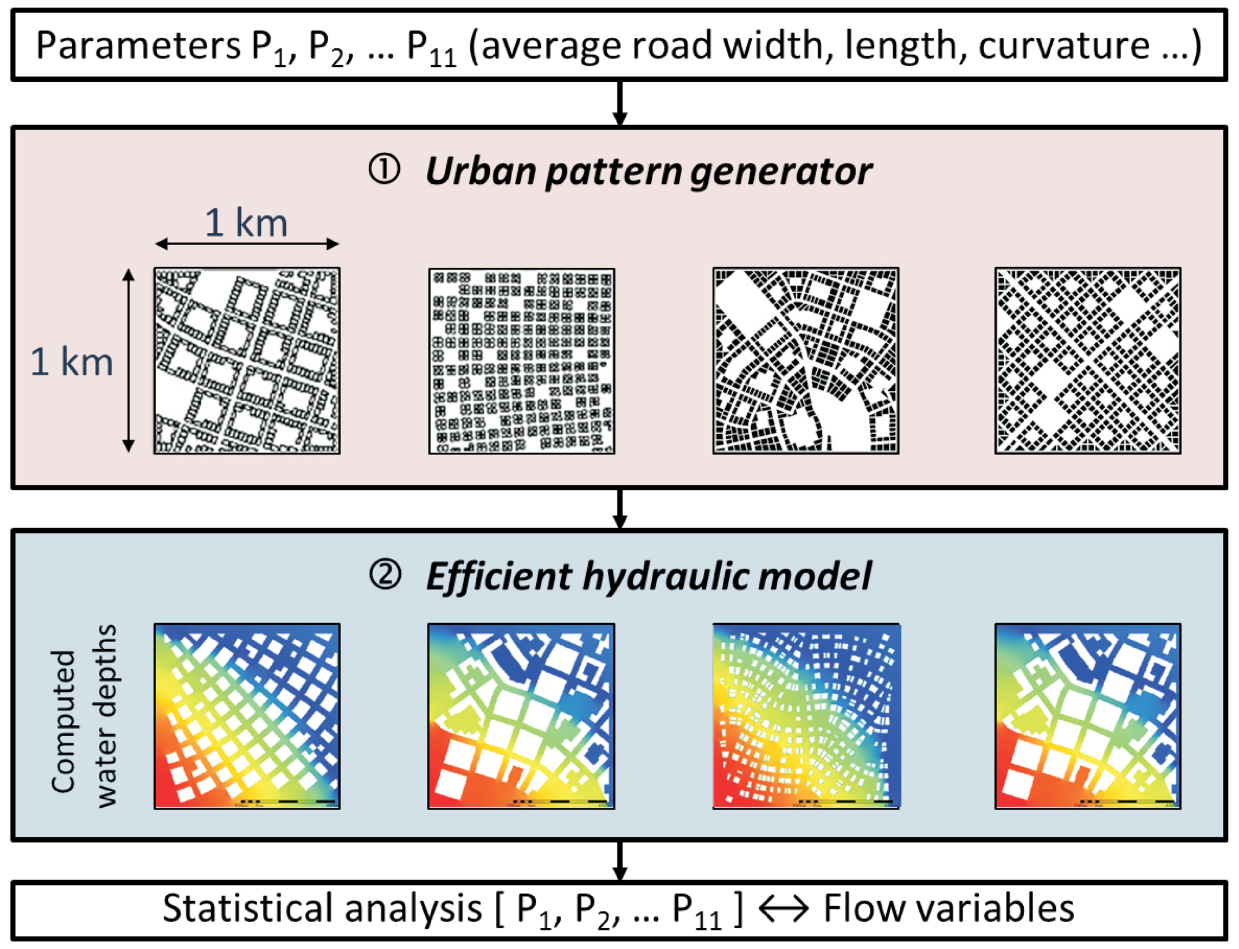
- Urbanization changes flood risk in many aspects, not only through changes in catchment hydrology.
- In parallel, high resolution topographic data are today widely available. While such very detailed data enable hydraulic computations with a high accuracy, the computational cost makes these computations hardly tractable.

Validation of an efficient porosity-based hydraulic model with a merging technique

Systematic analysis of the impact of urban pattern on flood flows in quasi-realistic configurations

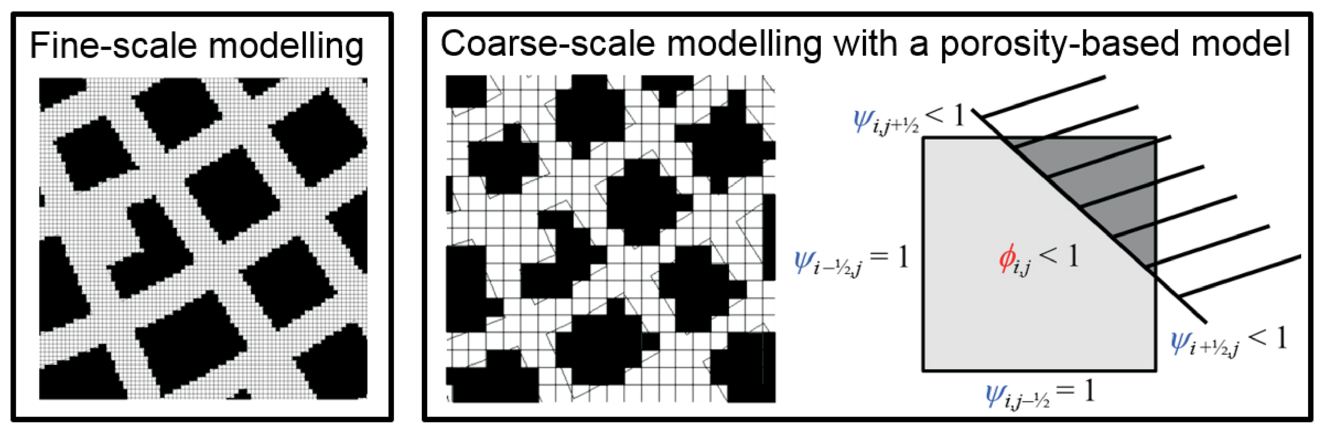
Methodology

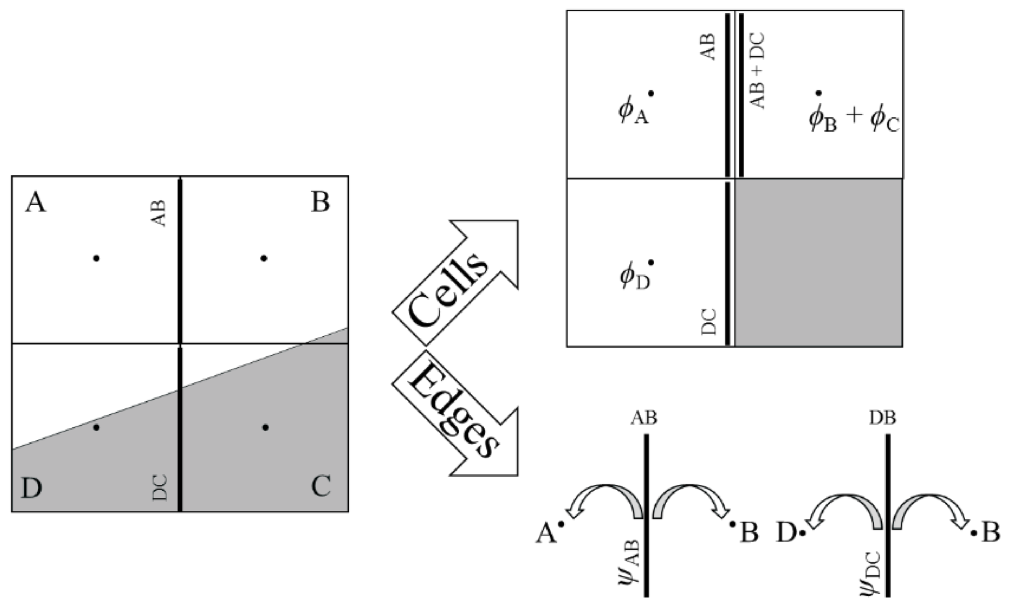
- Based on 11 urban parameters, thousands of urban networks are generated, representing a **wide range of urban configurations.**
- Flow variables are computed using an **efficient porosity-based model** at steady state.
- A **statistical analysis** is performed to evaluate the impact of the urban parameters on flood flows.



Shallow-water models with anisotropic porosity and merging

- Fine-scale topographic information is reproduced at a coarser scale through **porosity parameters to mimic the influence of the unresolved subgrid obstacles** on the different terms of the shallow-water equations.
- Two porosities are distinguished: a **storage porosity** (cell property) reflects the cell storage capacity and a **conveyance porosity** (edge property) reproduces the effects of obstacles on the conveyance capacity.



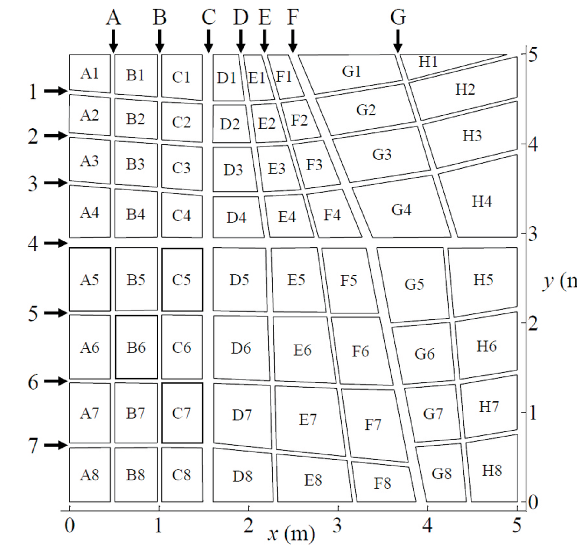


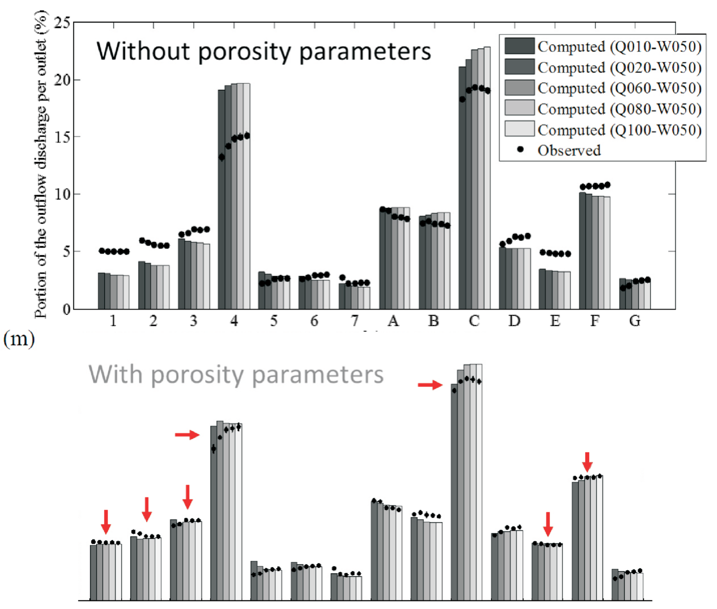
- For stability reasons, the computational cost may dramatically increase in the presence of very low storage porosities. This issue is addressed by incorporing an **original merging technique** within the porosity-based model.

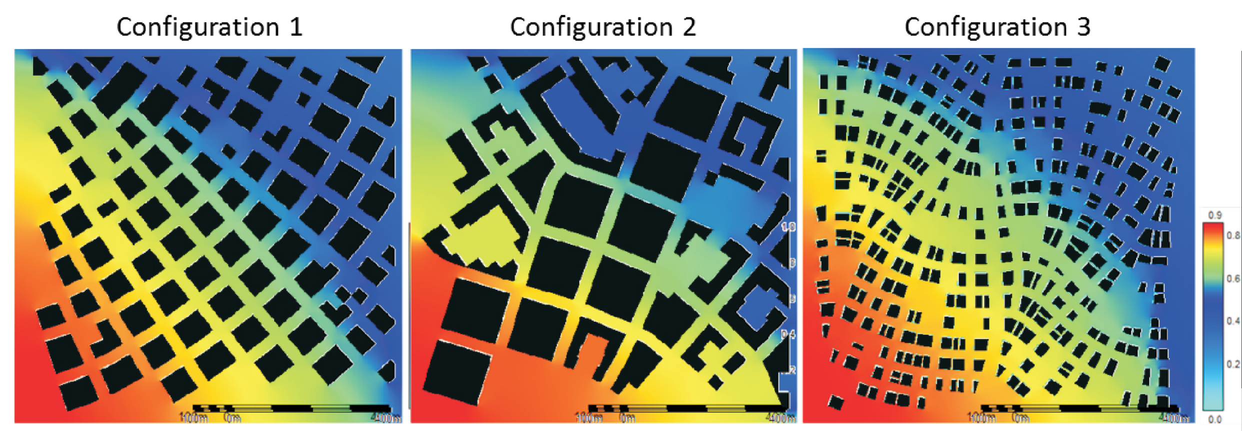
Validation of the porosity-based model

- Against a unique experimental dataset (Arrault et al., 2016. *Hydrodynamics of long-duration urban floods: Experiments and numerical modelling,* NHESS):

  ==> The root mean square error of the outflow discharge is reduced from 19% to 6.6% as a result of using the porosity-based model.







- Against results of fine scale computations:

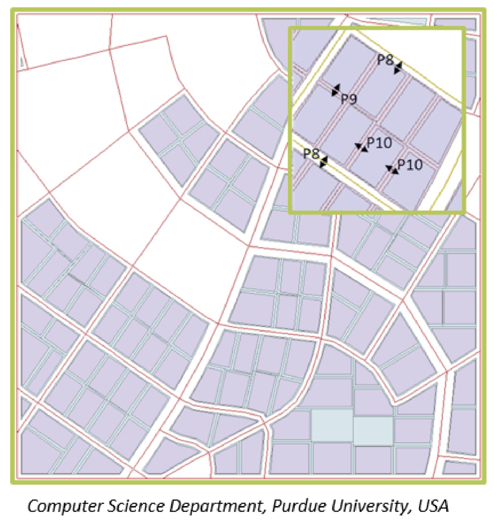
  ==> Increasing the cell size from 1 m to 10 m with a porosity-based model, the computational time is reduced by two orders of magnitudes while the porosity model error on water depth remains lower than 0.5% (~5% without porosity parameters).

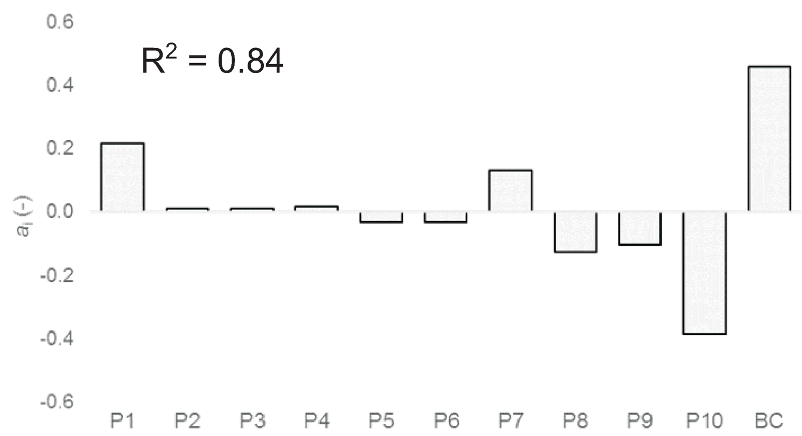
Statistical analysis

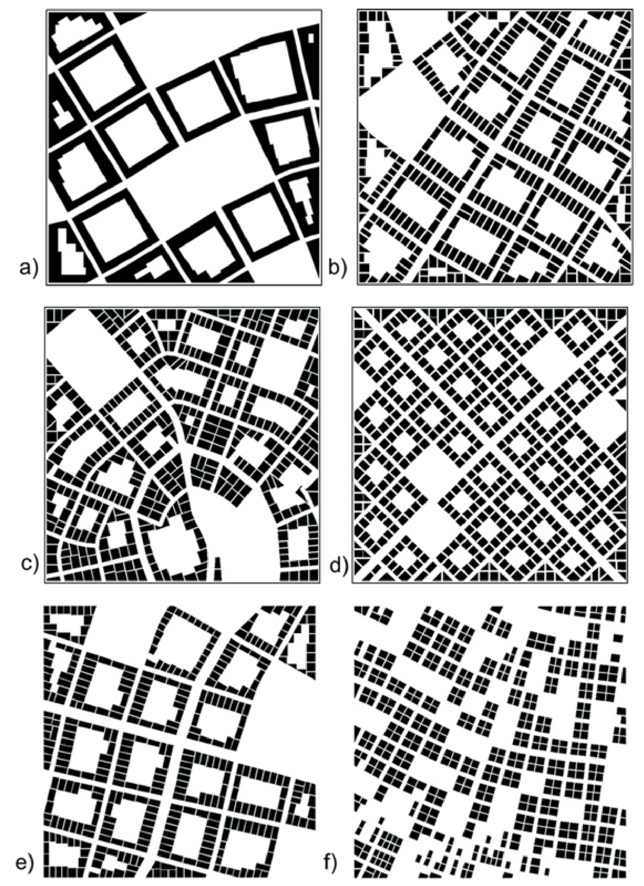
Two types of statistical analyses are conducted based on computations over ~7,000 urban networks.

- A **multivariate linear regression analysis** is applied to identify the relative influence of each urban parameter.

ID	Parameter
P1	Average street length
P2	Street orientation
P3	Street curvature
P4	Major street width
P5	Minor street width
P6	Park coverage
P7	Maximum parcel area
P8	Building front setback
P9	Building rear setback
P10	Building side setback
BC	Building coverage
	Derived from P1 to P10

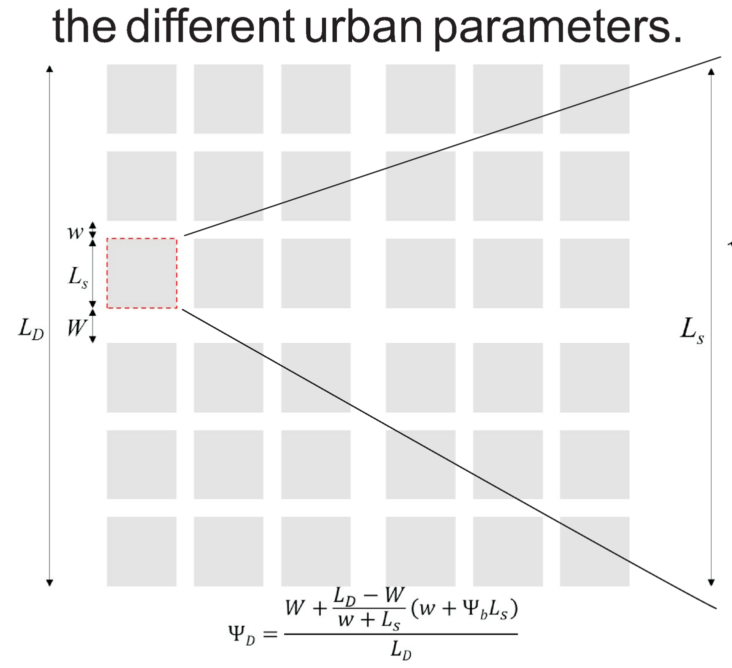


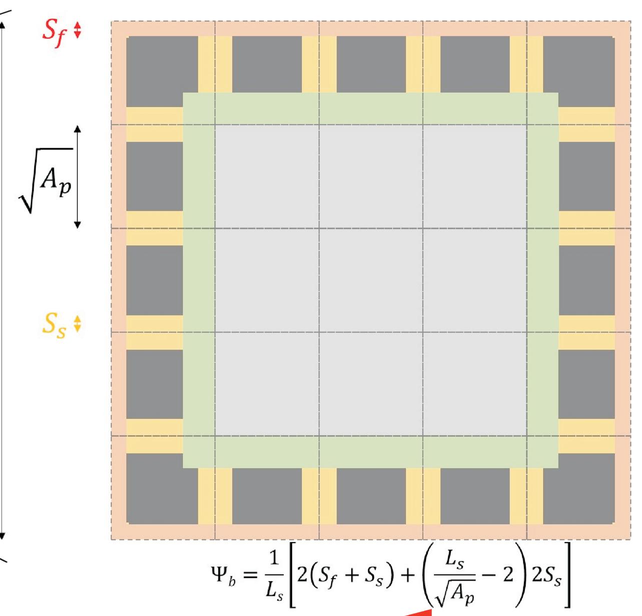


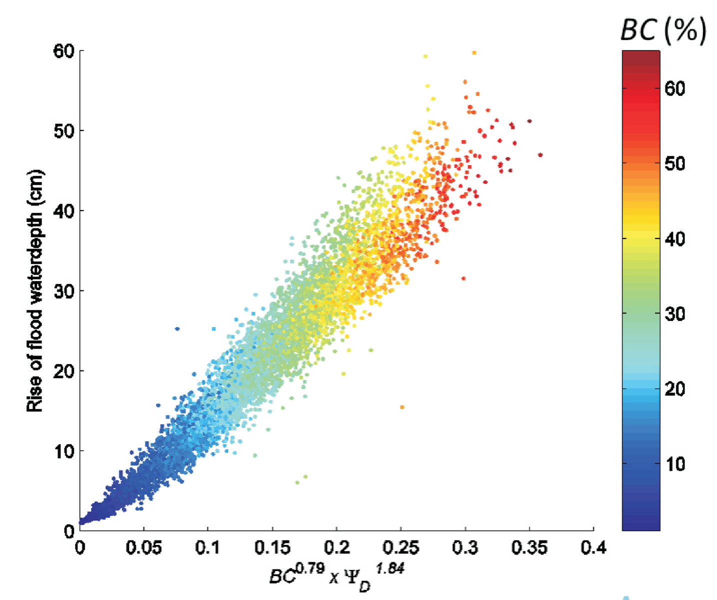


	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	BC	$h_{90\%}$
a)	0.57	0.28	0.63	0.38	0.58	0.65	0.74	**0.00**	**0.00**	**0.00**	0.74	0.73
b)	0.50	0.95	0.72	0.47	0.55	0.14	0.86	**0.32**	**0.57**	**0.64**	0.75	0.33
c)	0.32	0.09	0.93	0.23	0.10	0.14	1.00	**0.36**	**0.39**	**0.46**	0.88	0.49
d)	0.29	0.24	0.02	0.59	0.23	0.10	0.90	**0.22**	**0.25**	**0.71**	0.89	0.37
e)	**0.48**	0.52	0.55	0.85	0.38	0.57	0.75	0.48	0.34	0.41	0.71	0.45
f)	**0.09**	0.90	0.10	0.19	0.25	0.66	0.49	0.26	0.61	0.44	0.71	0.28

- A **simple mechanistic model** is built based on district porosity parameters combining the different urban parameters.







LIÈGE université

UEE Urban & Environmental Engineering

hece Hydraulics in environmental and civil engineering