Flash flood spatial analysis using hydraulic modelling and Geographic Information Systems

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U LISBOA | UNIVERSIDADE DE LISBOA
IGOT Instituto de Geografia e Ordenamento do Território UNIVERSIDADE DE LISBOA
CEG Centro de Estudos Geográficos
TERRA Laboratory for sustainable land use and ecosystem services
EGU European Geosciences Union

Introduction and study area

Context

- The relationships between **water depths**, **flow velocities** and **stream channel features** are theoretically well known and proven under controlled environments.
- These are **rarely explored and quantified** for case studies in different geographic contexts.

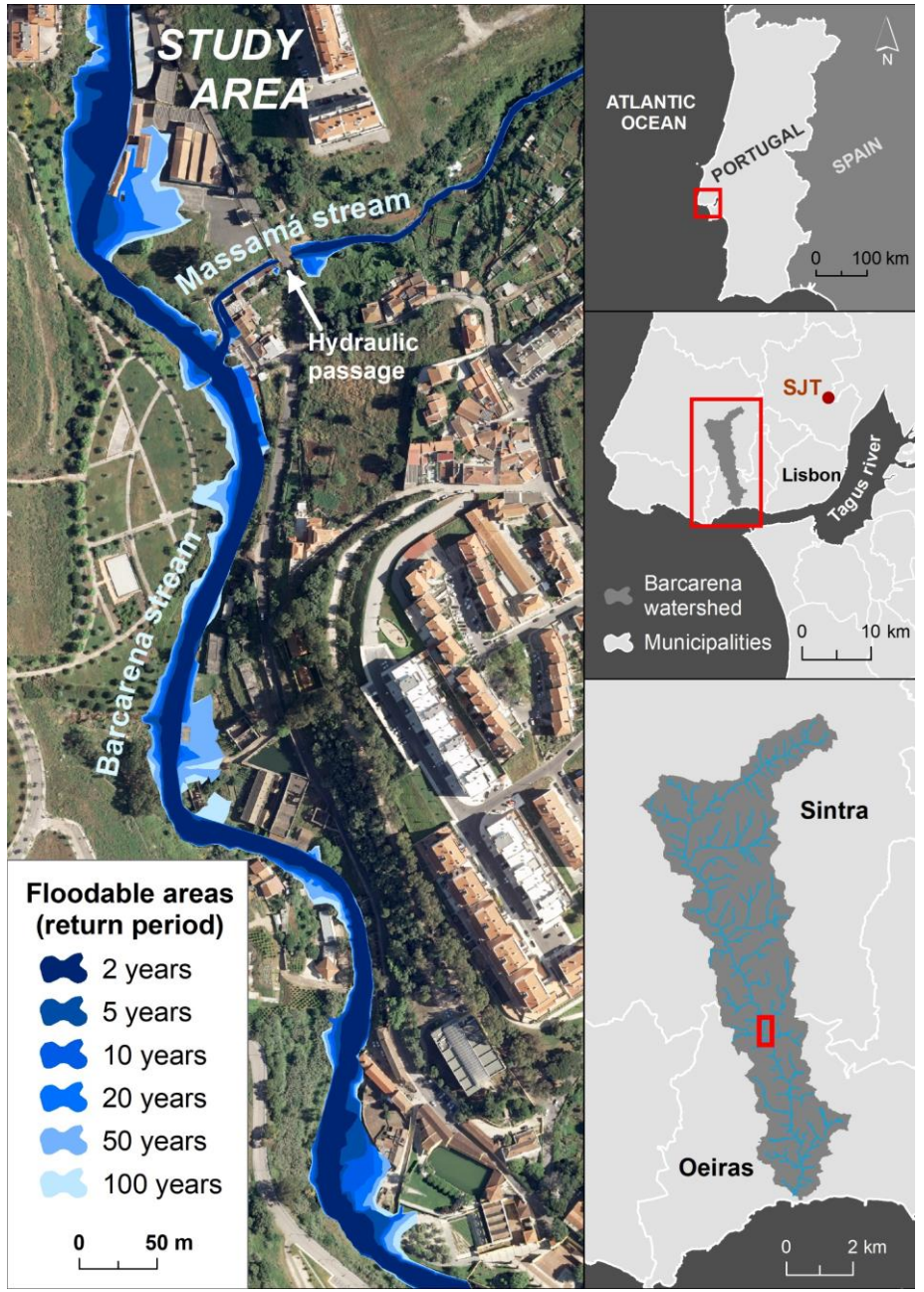
Main goal

Understand how **flow components** during **flash floods** are **spatially interrelated** and affected by **stream channel features.**

Study area

Small drainage basin in Portugal:

- 1000 meters of the Barcarena stream (main watercourse)
- The last 350 meters of the Massamá stream



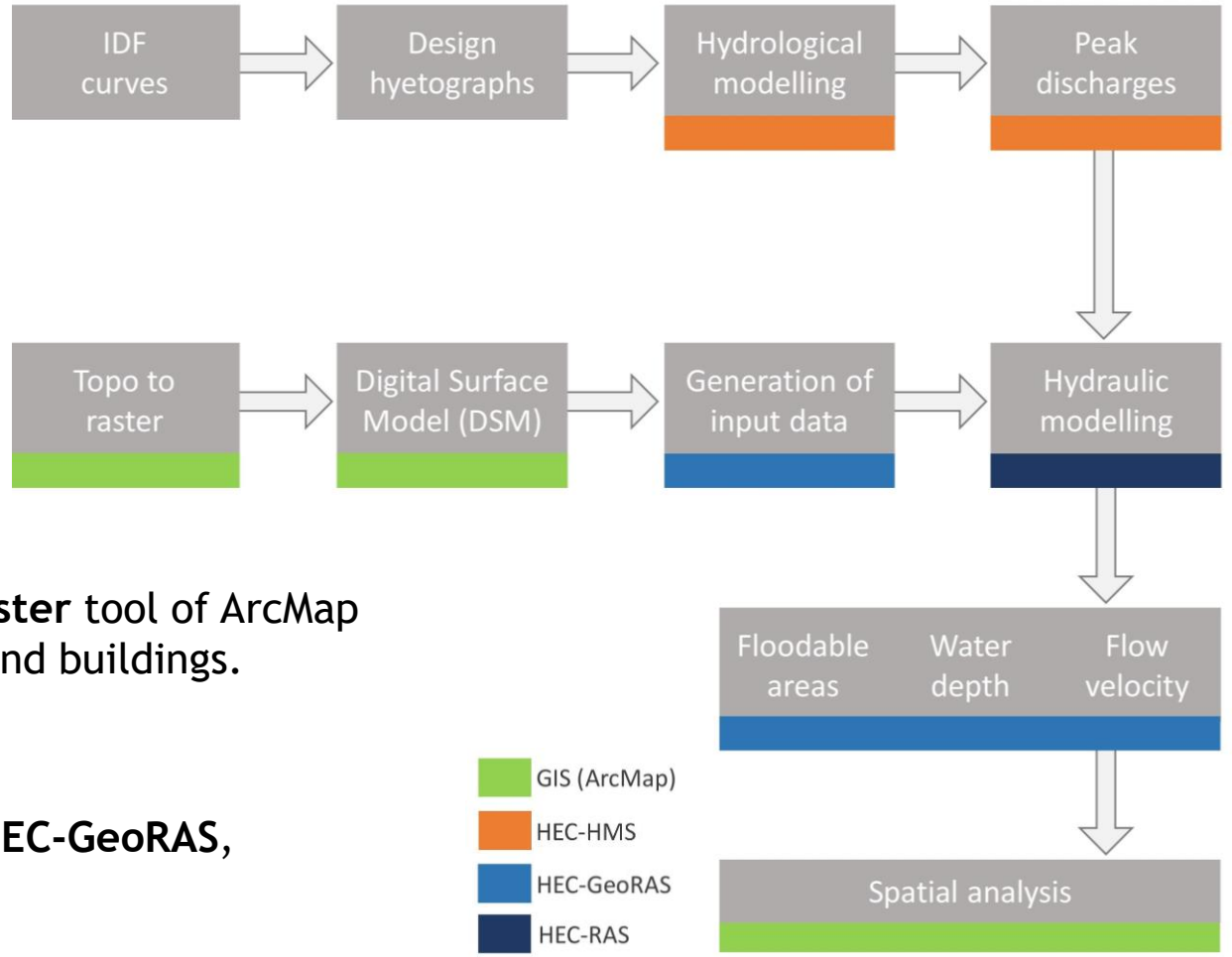
Data and methods

Spatial analyses were performed using **hydrological/hydraulic modelling** and **GIS** (Geographic Information Systems).

Peak discharges were obtained using hydrological modelling (HEC-HMS) due to the **absence of hydrometric data**.

A **Digital Surface Model (DSM)** was built through the **Topo to raster** tool of ArcMap using contour lines (1:2,000 scale), elevation points, thalwegs and buildings.

The **hydraulic modelling (1D)** was performed in **HEC-RAS** and **HEC-GeoRAS**, generating **quasi-2D flow velocity grids**.



The **calibration of the hydraulic model** was done through an **iterative process** using flood marks, testimonies from population, television reports and photographs of a 20-year R_T event (2008).

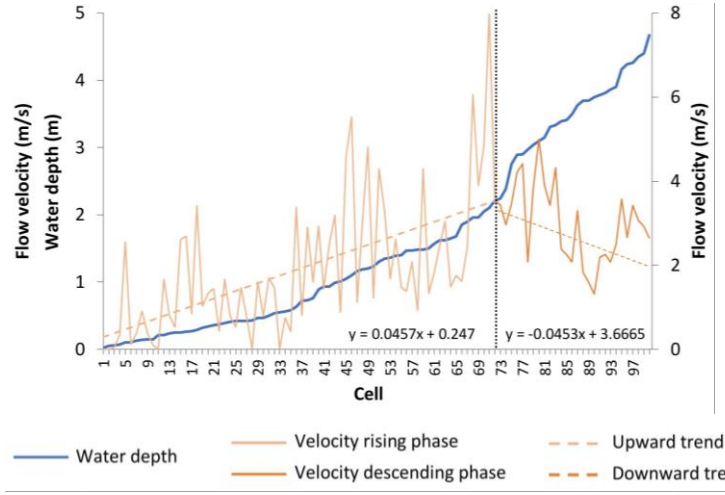
Results

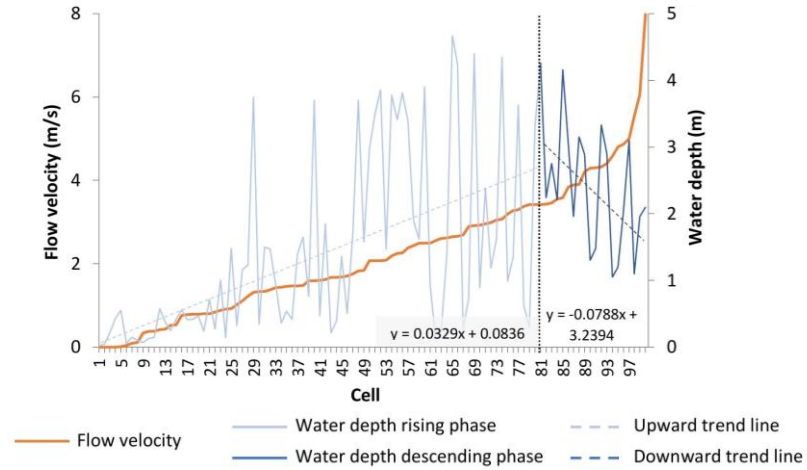
The **spatial relationships** between water depths and flow velocities point to positive moderate correlation coefficients in the **floodable areas** (**R = 0.50 for 100-year R_T**).

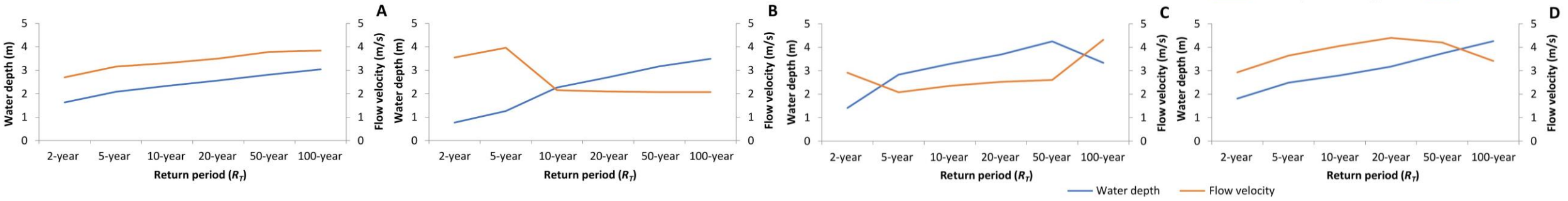
Water depths tend to **grow with increasing flow velocities** and vice versa.

This **trend changes when high values** of water depth or velocity **are reached**, preventing higher correlations.

The **spatial relationships** between water depths and flow velocities **can change** in result of **increasing peak discharges** and **return periods**.







Results

Unlike floodable areas, there are **strong negative correlations** between water depths and flow velocities **along the stream centrelines** (i.e., longitudinal maximum values).

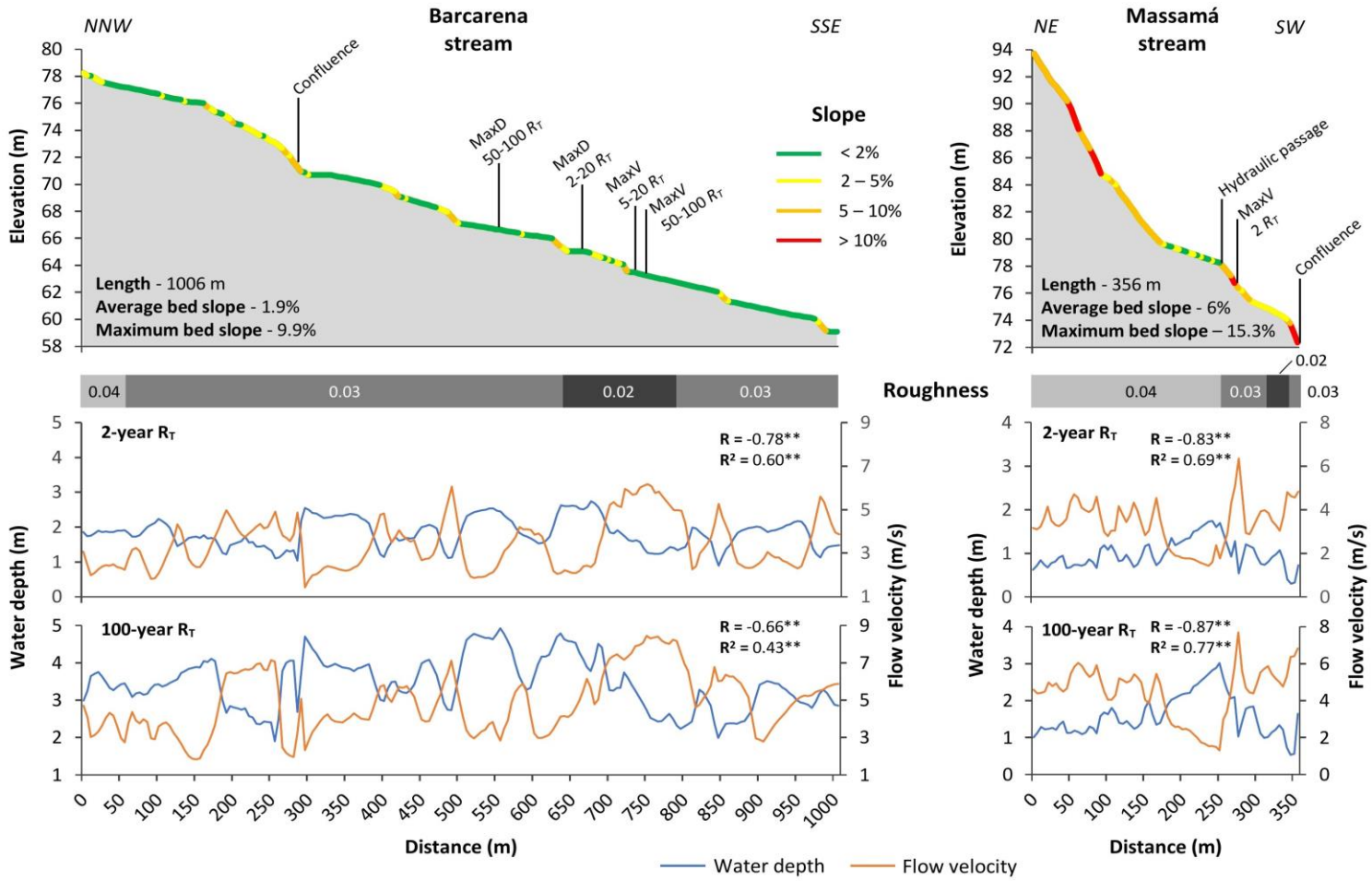
Correlation coefficients (R) between water depths and flow velocities:

Barcarena stream:
-0.78 (2-year R_T) and **-0.66** (100-year R_T)

Massamá stream:
-0.83 (2-year R_T) and **-0.87** (100-year R_T)

Correlation coefficients (R) between:

- Bed slope
- Channel width
- Flood width
- Water depths
- Flow velocities



	Barcarena				Massamá			
	Water depth		Flow velocity		Water depth		Flow velocity	
Return period (R_T)	2-year	100-year	2-year	100-year	2-year	100-year	2-year	100-year
Bed slope	-0.32**	-0.10	0.32**	0.11	**-0.57****	**-0.50****	**0.67****	**0.65****
Channel width	-0.33**	-0.11	0.03	-0.13	**-0.51****	**-0.51****	0.33**	0.38**
Flood width	0.18*	0.31**	**-0.48****	**-0.68****	-0.06	**0.46****	-0.14	**-0.49****

* Correlation is significant at the 0.05 level (2-tailed) ** Correlation is significant at the 0.01 level (2-tailed)

Discussion and conclusions

Limitations and sources of uncertainty:

- Lack of **hydrometric data** → compromises the **validation of flow velocities**
- Lack of **elevation data** along **stream channels** → compromise the **quality of the DSM**

Conclusions:

- **Good results** for floodable areas, water depths, longitudinal flow velocities, lateral velocities in straight sections and in mildly curved bends.
- **Errors** in sharp bends and at the confluence of Barcarena and Massamá streams.
- The spatial relationships between **depths** and **velocities** demonstrated positive moderate correlations in the **floodable areas** and strong negative **longitudinal** correlations.
- **Higher depths** are related to **low values of slope** and **higher velocities** are associated with **high slope** and **low roughness** sections.
- **Topo to Raster** guarantees the **transversal and longitudinal variations of elevation**, improving hydraulic modelling in **areas with scarce or no elevation data** along the channels.
- **Usefulness of GIS** to represent hydraulic modelling results and perform **spatial analysis** for flood events.

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Original paper:

Exploring spatial relationships between stream channel features, water depths and flow velocities during flash floods using HEC-GeoRAS and Geographic Information Systems

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