New trends in flood hazard mapping in urban area

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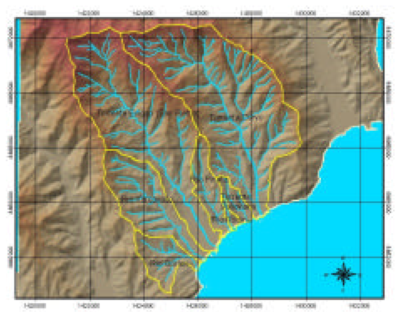
ABSTRACT: Definition of flood risk maps is a task to which modern surface hydrology addresses a substantial research effort. Their impact on the government of the flood prone areas have increased the need for better investigation of the inundation dynamics. This identifies open research problems such as: the definition of the design hydrograph, the choice of the conceptual hydraulic model and methodologies for flood hazard assessment.

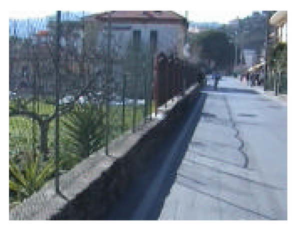
The aforementioned issues are here addressed by presenting a case study in a urban vulnerable coastal area in Italy. A new approach for the definition of the design hydrographs is investigated. The inundation is simulated with a quasi bidimensional hydraulic model that schematizes streets and aggregation of buildings as a network of channels and storages. The flood hazard is then evaluated, as defined in most recent directives for the river basin planning, on the basis of both hydraulic depth and flow velocity.

CASE STUDY

urban vulnerable coastal area in Italy



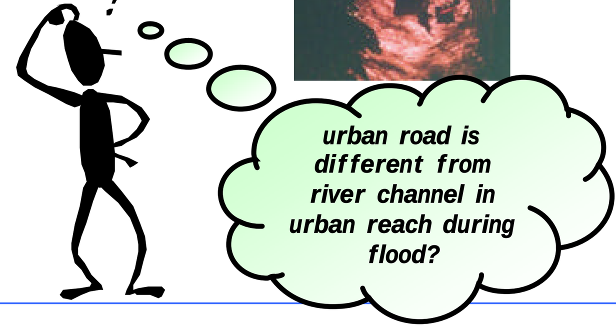
urban road



River channel in urban reach

urban road during flood

River	Area [km²]	Perimeter [km]	Average altitude [m a.s.l.]	Average slope [%]	Main river length [km]	CN II
Rio Gorleri	2.69	8.2	123.34	22.71	3.127	85
Rio Varcavello	6.37	12.92	164.43	27.87	6.26	85
Torrente San Pietro	18.05	23.42	353.78	32.55	10.93	84
Rio Pineta	2.48	9.2	134.14	24.13	4.21	85
Rio Rodine	0.32	3.046	40.56	12.8	1.27	87
Rio della Madonna	1.03	4.99	75.15	16.8	2.258	87



RDF CURVE

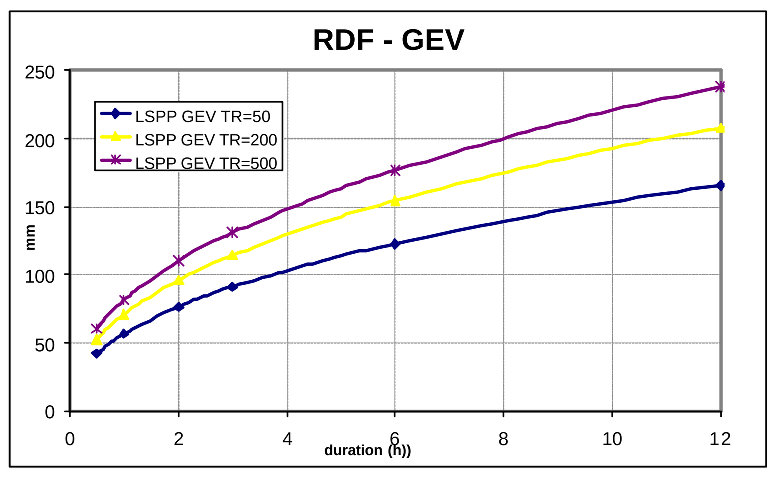
Rainfall-Duration-Frequency curve

GEV distribution

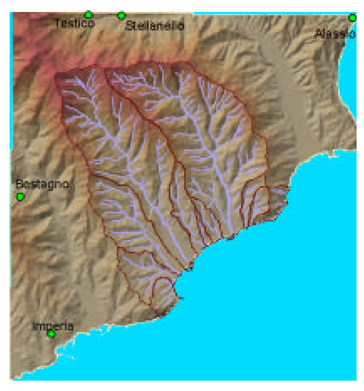
$$h_T(d)=a_1\cdot d^n\cdot w_T$$

$$w_T=e+\frac{a}{k}\left(1-e^{-ky}\right)$$

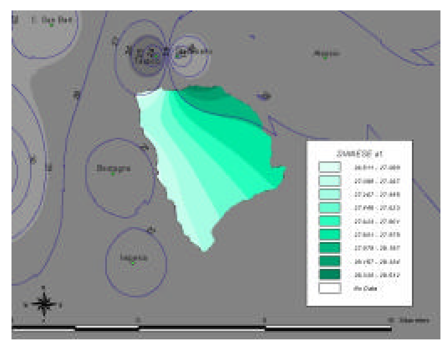
$$y=-\ln(\ln\frac{T}{T-1})$$



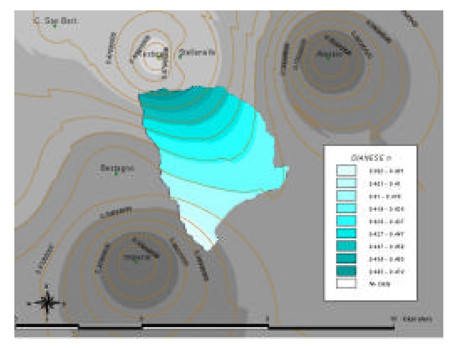
Rain gauges



a_1: spatial interpolation



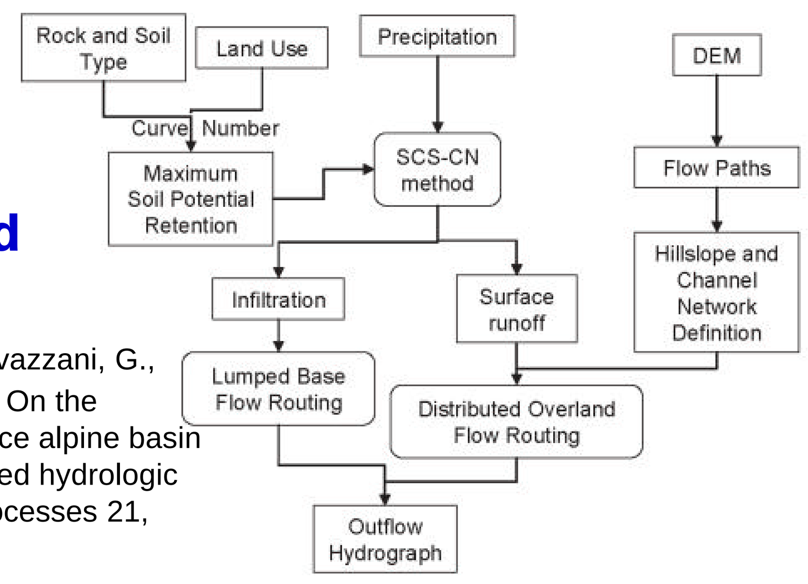
n: spatial interpolation



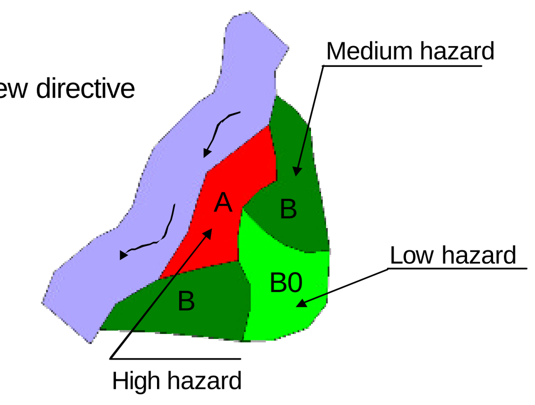
RAINFALL-RUNOFF MODEL

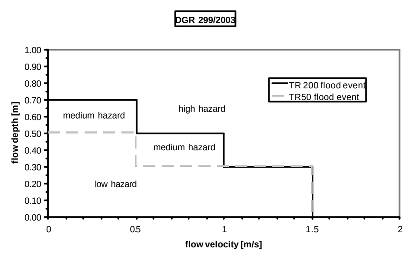
FEST* distributed model

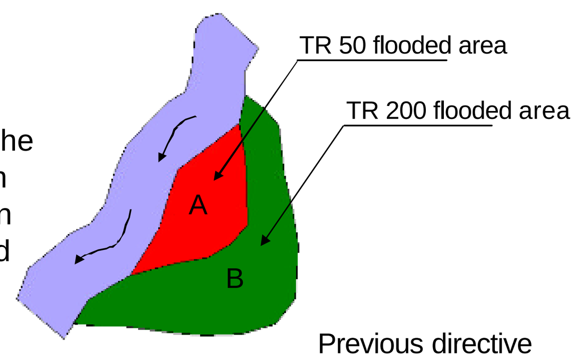
* Montaldo, N., Ravazzani, G., Mancini, M. (2007), On the prediction of the Toce alpine basin floods with distributed hydrologic models. Hydrol. Processes 21, 608-621.



NEW FLOOD HAZARD CRITERIA

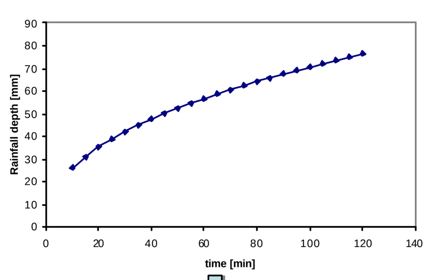




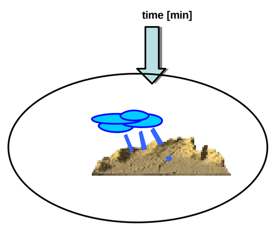


A new scheme recently proposes to determine the hazard map on the basis of both hydraulic depth and flow velocity. According to this scheme, if an area is frequently flooded but with low depth and low velocity, the class of hazard is lowered. Moreover a new hazard class is introduced. According to the new scheme, area can be classified as class-A, class-B and class-B0 hazard. The class-B0 area is the less restrictive one.

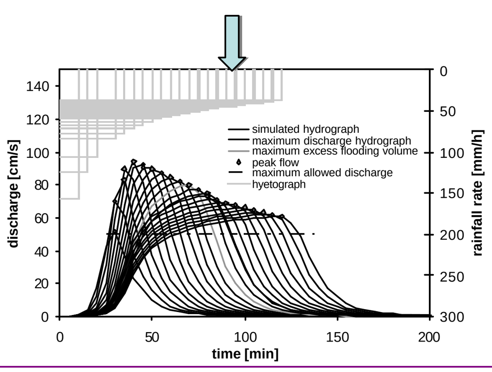
DESIGN HYDROGRAPH



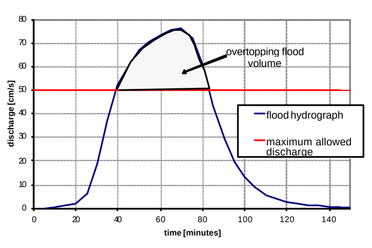
Rainfall-Duration-Frequency curve

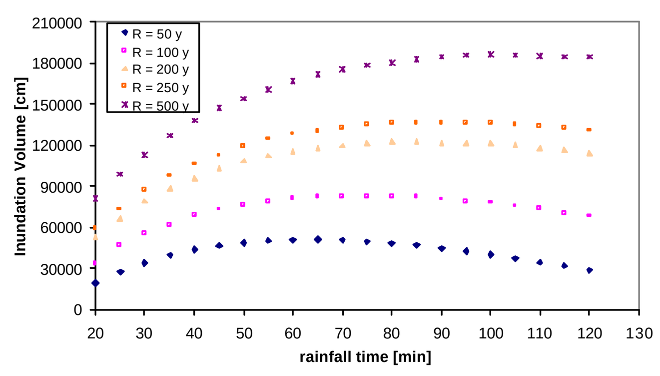


Rainfall-runoff transformation:



Simulated hydrographs

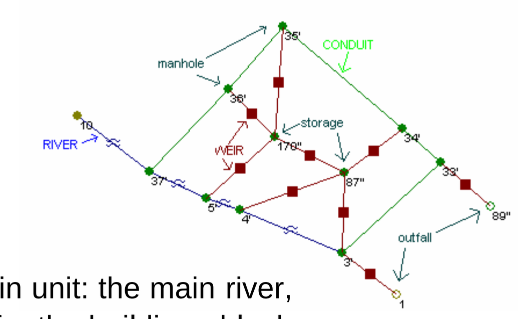




Series of potential inundation volume for different return period. The design hydrograph for a given return period is the one characterized by the maximum value of the potential flooding volume.

HYDRAULIC MODEL

INFOWORKS-CS
Wallingford Software



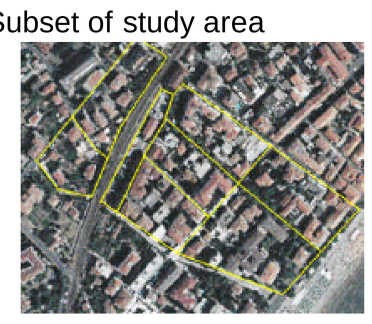
the implemented network model presents three main unit: the main river, the channel along the main street and the storage for the buildings blocks. De Saint Venant equation are integrated along the river branches and street channels. Reservoir equation is used to model diffusion in the blocks.

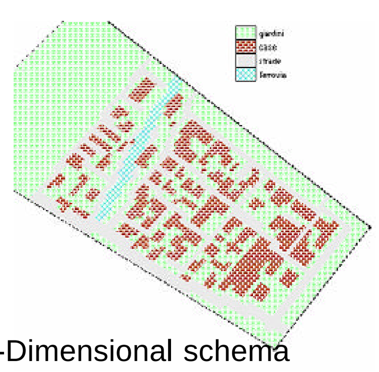
The connection between storages and channels are discretized in the specific nodes and the weir equations controls the water flux to and from the reservoir according to the difference of water level.

When the riverbanks are overtopped, water enters the street channels.

2-D MODEL

Subset of study area

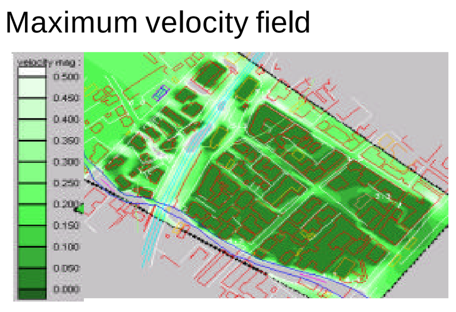




2-Dimensional schema

SMS (Surfacewater Modelling System)

Maximum velocity field



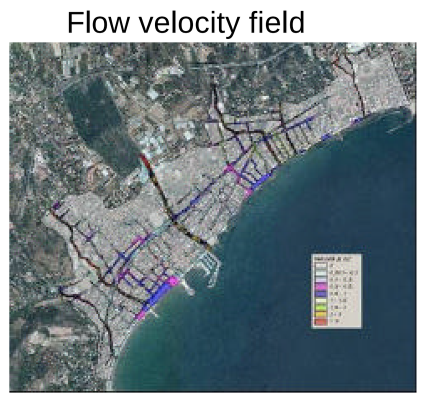
A full 2-D model was implemented using the SMS software (Boss International). A steady analysis has been performed. Hydraulic depths deriving from channel network simulation have been taken as boundary condition on the border of districts.

Buildings have been treated in two different ways: as impervious area (buildings are excluded from the model domain) and as a high roughness surface (Strickler coefficient equal to 0.01 m1/3s-1). Both considering buildings impervious or as high roughness surface, the peak flow velocity reaches, anyway, a maximum value of 1.3 m/s in a few cells.

We can conclude that motion of water in the districts is characterized by low values of velocity. The assumption to simulate blocks as storages in the channel network model seems reasonable.

HAZARD MAP

Flow velocity field



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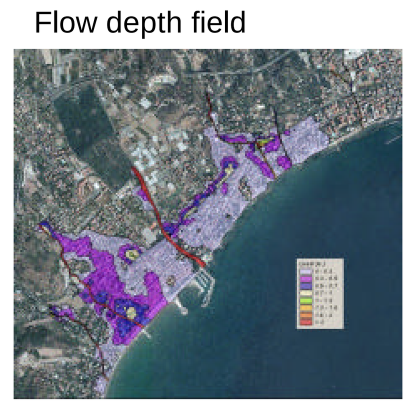
Flow depth field



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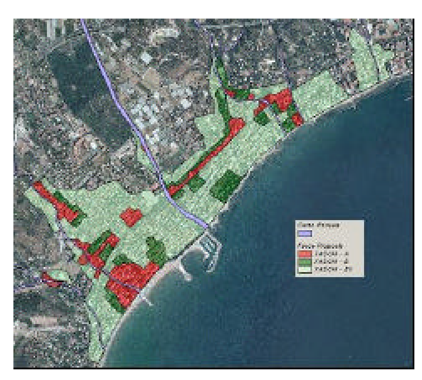
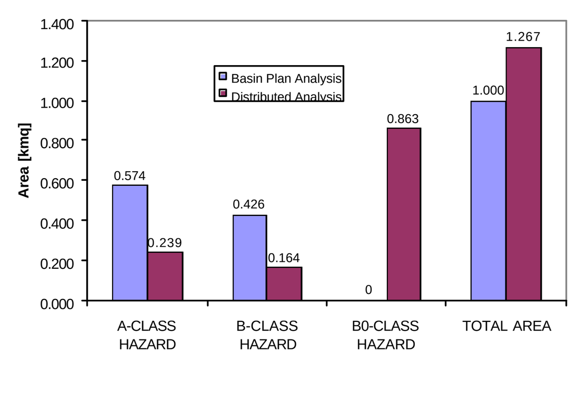
HAZARD MAP



STUDY COMPARISON



CONCLUSIONS: A procedure is presented for estimation of design hydrographs. It is based on the search for the critical event which maximizes the potential flooding volume. The iterative process makes use of the FEST model for the rainfall-runoff transformation. The distributed model permits to well represents basins characterized by heterogeneous morphology and land use, as the ones in this work. The critical event guarantees that the hydrograph with the maximum effect on territory is assumed, even if peak discharge is lower than the maximum peak discharge for the given rainfall frequency.

Classical one dimensional models are poor tools for flood analysis in urban area. They can be used till main stream is not overtopped, as they fail to simulate flow component other than along river direction. Two dimensional models, on the other hand, are time consuming and, for unsteady flow simulations on complex topography, they fail on steep slopes, geometric discontinuities, mixed flow and initially dry areas.

This work proposes an hybrid approach. The urban and drainage system is modelled by means of a network in which both rivers and roads are modelled as channels linked by nodes. The basic assumption is that high density urban blocks can be modelled as storages in which flow velocity is null. The assumption is confirmed by 2D model results which confirm that flow velocity in the districts is negligible.

The channel network model seems to well represents flood routing in urban area, it is not computationally expensive as 2D model and, above all, is much more stable on complex topography than 2D model. On the other hand it requires a deep knowledge of the territory and a good skills of the modeller to set up the hydraulic sketch.