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URBAN FLOODS: MODELS USED IN BRAZIL

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ABSTRACT: Brazil has been faced with many problems regarding urban floods. In order to predict and prevent the devastating impacts that these events might have on society many computer models have been used in the past decades. The main objective of this work was to do a literature review of the models used in Brazil for urban floods. We surveyed data found in Brazilian literature, using only virtual bases. We finally selected fifteen papers written in Portuguese and analyzed their results and coefficients of efficiency. Most papers were published in the Revista Brasileira de Recursos Hídricos after the year 2000, and there were 15 different models used. We could illustrate the models and their applications in Brazil, however there were few papers in Portuguese and we should expand our search to include the works published in international journals as well.

Keywords: urban floods in Brazil; computational modeling; efficiency of the methods.

1. INTRODUCTION

Urban floods have had a worrying negative impacts on Brazilian society (TUCCI, 2013). The increase in occurrence of these events, observed recently in Brazil, have attracted increasing interest from many sectors of society, aiming at anticipating and reducing these impacts in terms of livelihood and property damage (MELLER et al., 2012). The hydrological model is a developed tool used to understand and represent the behavior of the watershed (TUCCI, 2005).

In the last years, models have been gaining ground for letting the spatial variability of watershed characteristics to be incorporated in the rainfall-runoff transformation process (COLODEL, 2009). For its application is essential that the data series (hydrological and hydraulic) be reliable (PAIVA, 2001). There are many hydrological models, each aiming specific purposes and using different mathematical formulations to simulate the flood process (COLODEL, 2009). When choosing the most appropriate model, a few points should be considered: conditions of the watershed; the necessary data; complexity; the accuracy and validity; the spatial and temporal variation; model components; and especially, the user goals (MERRITT et al., 2003). The objective of this paper was to review existing studies in the Brazil that address hydrological modeling as a tool to understand the processes related to floods. Regarding the problem faced in Brazil in view of the floods that affect urban areas and the quantity of existing models, the models used and its main characteristics were listed, in order to facilitate the choice of the most appropriate model for each study.

2. METHODOLOGY

The study was prepared by surveying data found in Brazilian literature. Which were exclusively directed to studies of floods in the application of computational modeling. The review is based on exposing studies and their results.

The research was started with articles search in online databases (e.g. Brazilian Journal of Water Resources - RBRH, CAPES journals, etc.). It is important to point out that the databases searched are publications in Portuguese. The electronic bases were consulted in 1998 until 2013, from June to July of last year, using the following keywords: *"inundações urbanas"; "inundação urbana"; enchentes; modelagem computacional"; modelos hidrológicos".* During the initial selection the articles were evaluated by the titles and abstracts to verify the framework of the theme. Subsequently, the work identified the initial strategy were reviewed one by one, making sure the compatibility with the theme, and organizing a document with the partial summary which contains the points considered most important: title, model used, objectives of study, results, difficulties and facilities.

After an initial screening of the 46 papers found we selected 15 to review. The exclusion criteria were: studies that analyzed the floods with only the use of a GIS system, dissertations and doctorate theses. The exposure of the results obtained by the authors is made of exhibition tables and descriptive way in order to facilitate the reader understanding.

3. RESULTS AND DISCUSSIONS

Hydrological modeling is an important assistance tool to making a decision on projects involving water resources (MARINHO FILHO et al., 2000). The basic limitations of hydrological models are the quantity and quality of data, some processes and simplification of the spatial distribution of variables and phenomena (TUCCI, 2005). Because of these limitations, many different models are founded, and their mechanisms differ in the detail of the processes, which may hinder the choice of the most appropriate method. Table 1 lists the templates founded, as described in the methodology of this study.

Table 1 - Models used in Brazil for urban floods studies, authors, year, study area and journal.

MODEL	AUTHOR	YEAR	STUDY AREA	JOURNAL
IPHS-1/HIDRORAS.	Barros et al.	2007	São Paulo	RBRH
IPH4	Campana e Tucci	1999	Rio Grande do Sul	RBRH
ModCel	Carneiro et al.	2010	Rio de Janeiro	Ambiente & Sociedade
SMAP/ ETA-CPTEC	Castanharo et al.	2007	Paraná	RBRH
DPFT/Redes Neurais Artificiais	Cruz	2010	Minas Gerais	RBRH
ETA/MGB-IPH	da Silva	2007	MG/BA/PE/ SE/AL (Bacia do Rio São Francisco)	RBRH
Método PVP (TCEV e GRADEX)	Fernandes e Naghettini	2007	Minas Gerais	RBRH
SWMM	Garcia e Paiva	2006	Rio Grande do Sul	RBRH
AHP	Magalhães et al.	2011	Espírito Santo	Cadernos de Geociências

A e C2/ MOUSE	Meller e Paiva	2007	Rio Grande do Sul	RBRH
MGB-IPH	Meller et al.	2012	São Paulo/ Minas Gerais	RBRH
Células de Escoamento	Miguez e Mascarenhas	1999	Santa Catarina	RBRH
MCT	Pontes e Collischonn	2012	Minas Gerais	RBRH
MacCormack	Suleiman e Barbassa	2005	São Paulo	Ciência e Engenharia
Topmodel	Varella e Campana	2000	Distrito Federal	RBRH

There is a considerable variability of the models found, which differ in complexity, processes, scales, in cases for which they are applied. The IPH (Institute of Hydraulic Research, Federal University of Rio Grande do Sul) model package is the only one who presents repeated application this fact can be associated to the models being developed in Brazil. The Revista Brasileira de Recursos Hídricos - Brazilian Journal of Water Resources (RBRH) is the one which more publications for this theme, with editions since 1999.

The “best model” should be the one that supports the data needed for your application (input), as well the objective, and the results you want to achieve (output). Defined variables, the error probability decreases, causing more efficient results. In Table 2, are presented the specific objectives descriptions for each model, according the selected study.

Table 2 - Specific objectives descriptions according the selected study.

MODEL	**SPECIFIC OBJECTIVES**
IPHS-1/HIDRORAS.	Critical events were simulated using integrated rainfall-runoff transformation, through the models IPHS-1 and HIDRORAS, whose results were compared. The purpose of this work is to provide information to support decision-making in the Master Plan.
IPH4	In this study is presented the relationship between the hydrologic models and Urban Plan parameters. Hydrologic model IPH IV and GIS were used to forecast the hydrograph from some urbanization scenarios.
ModCel	Evaluate the impact caused by the urbanization expansion, as well the impact of sea level elevation in the drainage of watershed conditions, as the IPCC estimates.
SMAP/ETA-CPTEC	A short-term discharge forecast model with a 12-day horizon for a specific basin.
DPFT/Redes Neurais Artificiais	The comparison of two flood forecasting methodologies (DPFT and Redes Neurais), using models with few parameters to calibrate.

ETA/MGB-IPH	Presentation of the results of integration between ETA atmospheric regional model and MGB-IPH distributed hydrologic model, to short-range streamflow forecast.
Método PVP (TCEV e GRADEX)	Describe the essence of PVP method (three principles to improve estimates of extreme flow quantis: replacement for the space, adding more structure to models, focus on the top because of the probability distributions), and illustrate their use applying in a basin.
SWMM	Evaluate the applicability of the Storm Water Management Model (SWMM) in a monitored urban basin, analyzing the changes that occurring in the hidrograma de cheia for three periods with different use and land cover.
AHP	Comparasion two different methods for mapping areas susceptible to flooding risk.
A e C2/ MOUSE	Simulation of a simplified methodology for urban flood, applied to a small catchment using observed data.
MGB-IPH	This paper presents an empirical data assimilation method applied to a real-time flood in a medium-size basin located in outheastern Brazil
Células de Escoamento	The main purpose of the present study is modeling flood behavior in urban areas.
MCT	The present paper evaluates the Muskingum-Cunge-Todini (MCT) method comparing it to other streamflow routing methods in a hypothetical canal,
MacCormack	This paper proposes a methodology aiming to provide a computational tool to outline areas with higher or lower risk of flood for planning a draining system and urban use. A hydrodynamic propagation model was developed by using the MacCormack explicit scheme, making it possible to be applied in urban channels.
Topmodel	This study focuses mainly on the the analysis of the influence of the spatial resolution of the DTM in model's performance.

Out of other objectives found in the works the hydrological models are applied to rainfall-runoff transformation, simulating the response in an interest section basin. Studies comparing the methods were also found, as well as the simulation of scenarios. According to Fragoso et al., (2009) the greater the number of parameters and external variables involved in a process calculations, is the best approximation to reality, greater complexity and difficulty of their estimates. Table 3 describes some input/output data of selected models, and the degree of efficiency defined by statistical coefficients (when specified by the author).

Table 3 - Description of input/output data mode, referring to the selected studies as well as statistical coefficients of efficiency, when specified by the author.

MODEL	**INPUT**	**OUTPUT**	**Nash/R^2**

IPHS-1/HIDRORAS.	geometric data; DTM; key curve; rain; flow; speed	flow rate	
IPH4	DTM; rain; flow; hydraulic data	flow rate	0.96 (R^2)
ModCel	DTM; rain; flow; hydraulic data	flow rate	
SMAP/ ETA-CPTEC	DTM; rain; flow; evapotranspiration, soil saturation capacity; groundwater charging	flow rate	
DPFT/Redes Neurais Artificiais	DTM; rain; flow; evapotranspiration; maximum capacity of the reservoir; initial volume of the reservoir	flow rate; rain	
ETA/MGB-IPH	DTM; flow; rain; soil humidity	flow rate; runoff volume	28.55% (error)
Método PVP (TCEV e GRADEX)	DTM; rain; flow; hydraulic data	flow rate; runoff volume	
SWMM	DTM; rain; flow; hydraulic data	flow rate; runoff peak volume	0.95 (R)
AHP	DTM; rain; flow; hydraulic data	flow rate; runoff volume	6.13% (error)
A e C2/ MOUSE	A: concentration time; time-area histogram; C2: early losses; losses during the event; MOUSE: Manning coefficient; head loss	flow rate;	0.9 (R) Qpeak 5% Vflow 20% (error)
MGB-IPH	DMY; flow; rain; soil type	flow rate; runoff peak volume	0.9 (Nash)
Células de Escoamento	DTM; rain; flow; hydraulic data	flow rate; runoff volume	
MCT	Flow; speed; precipitation	flow rate; runoff peak volume	0.00% 0.01% -0.80% -0.33%
MacCormack	DTM; rain; flow; curve key	flow rate; speed; runoff volume	6.07%
Topmodel	DTM; rain; evapotranspiration; flow	flow	

The streamflow prediction is becoming increasingly common, for creating urbanization scenarios through the use of hydrological models. In this study four models have focused their goals for this purpose: IPH4; SWMM; MacCormack; ModCel. The scenarios created by Campana and Tucci (1999) for IPH4 model; and Paiva and Garcia (2006) for SWMM were based on the behavior basin (urbanization) for current and

future conditions, as well a past situation considered with reference, and return times of rains project. Suleiman and Barbassa (2005) defined a river stretch where the scenarios were created from the changing conditions of hydraulic and hydrological parameters. Carneiro et al., (2010) that works with ModCe) apply the population dynamics changes, and the sea increase level, to assess the impact on the basin hydrodynamics. The comparisons between methods are common in studies, being done from statistical coefficients. The models were compared: IPHS-1 e HIDRORAS; DPFT e Redes Neurais; método AHP; variações do MCT. The results of these comparisons are described in Table 3.

The intention is to help the reader choosing which is the most appropriate model, so listing the objectives and results; it is important to highlight some of the difficulties encountered by the authors. Barros et al., 2007 reports uncertainties in the calibration of IPHS-1 which consists in SCS designing methods and in the absence of being able to represent the movement of the cell in the basin rainfall, stormwater drain, bridges, etc. Castanharo et al., (2007) describes about the inaccuracies in the simplifications used by models and observed data, the author then examines ten versions of the proposed method. Have Magalhães et al, (2011) mentions the overestimation of AHP model for flood risk in relation to the data generated in field survey. One of the major difficulties reported by most authors is the large amount for some models, and the absence of a long-period data (e.g. hydrological, meteorological) for the study areas.

4. CONCLUSIONS

Considering the exposed studies, notice the importance of quantification of hydrological processes for urban areas, and the use of computer models, even with its limitations, to verify the interactions and systems modifications. The initial objective of exposing the models used in Brazil was reached, but realizing the need to expand research for databases that are not necessarily in Portuguese, since the reduced amount of articles selected before the initial screening.

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