Assessment of Channel Flow Depth in a Data-Scarce Urban Catchment of Eastern India

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Abstract

Nowadays, many of the world cities and its peripheral areas are under constant threat of flooding due to high rainfall events. Increased rate of severe flood hazards world-wide have created a demand for understanding the flooding behaviour across various urban and peri-urban catchments. However, simulating the flooding scenarios under limited hydrological data condition is a great challenge for the urban water planners and managers, especially in developing countries. To this, in this study, a combined modelling approach is proposed with the physically based Variable Parameter Muskingum Stage (VPMS) routing model to develop a local rating curve for generating the discharge data from the available stream stage data, which was subsequently used as an input to the Storm Water Management Model (SWMM). The coupled methodology is applied in a typical ungauged urban and peri-urban catchment of eastern India. The proposed SWMM-VPMS model is calibrated for the monsoon (rainy) season of the year 2009, and validated for the monsoon seasons of 2011 and 2014. The performance of the model is satisfactory with the Nash-Sutcliffe efficiency (NSE) estimates of 0.82, 0.89, and 0.89 for the years 2009, 2011, and 2014, respectively. The proposed SWMM-VPMS model can be used for a catchment where the tributary is ungauged while the main river is gauged at a downstream location of the confluence point. This methodology can also be adopted in catchments with missing rating curves. Additionally, the information regarding spatial distribution of channel flow depth at different time can be utilised to have an initial assessment of the flood-vulnerable areas. Keywords: VPMS; SWMM; Urban and peri-urban catchment; Ungauged catchment

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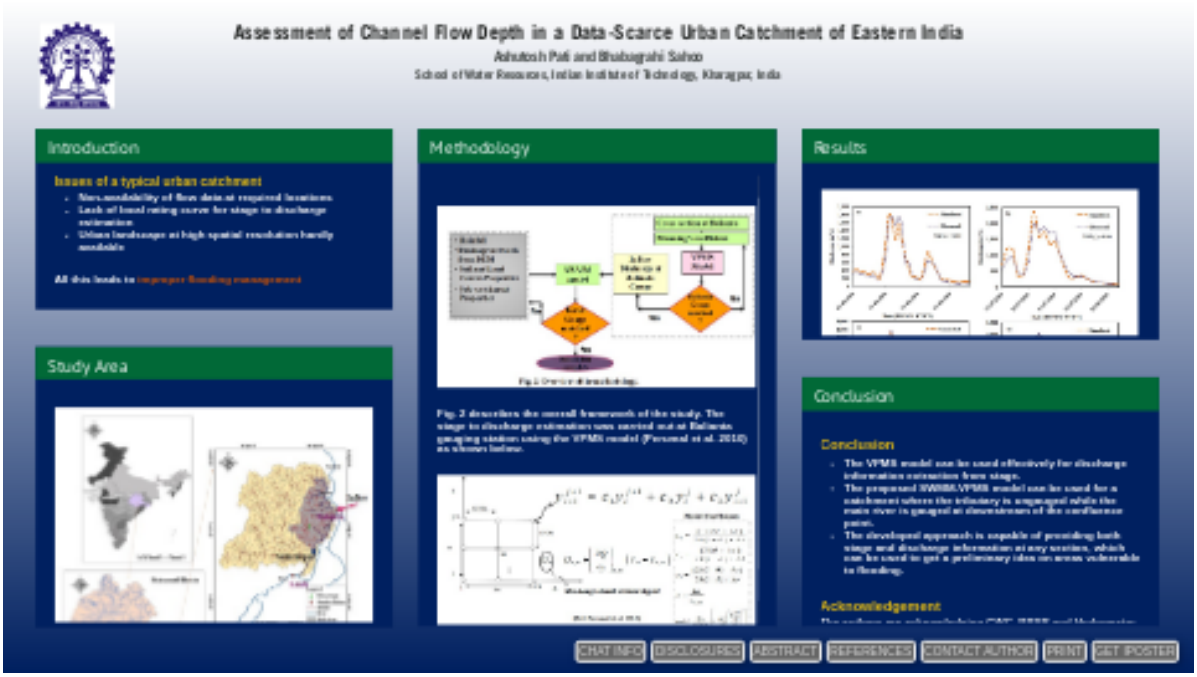

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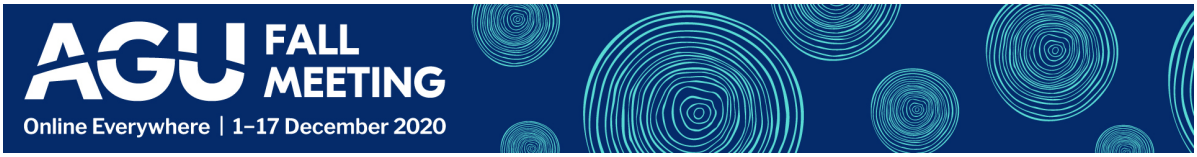

INTRODUCTION

Issues of a typical urban catchment

- **Non-availability of flow data at required locations**
- **Lack of local rating curve for stage to discharge estimation**
- **Urban landscape at high spatial resolution hardly available**

All this leads to improper flooding management

Focus of the Study

- **To estimate the discharge at a location from stage data using Variable Parameter Muskingum Stage (VPMS) model**
- **To set up the urban catchment by coupling the Storm Water Management Model (SWMM) and the VPMS model for the monsoon season of 2009, 2011 and 2014**
- **To estimate the flow depth at the Nistarinipur (urban outlet)**

STUDY AREA

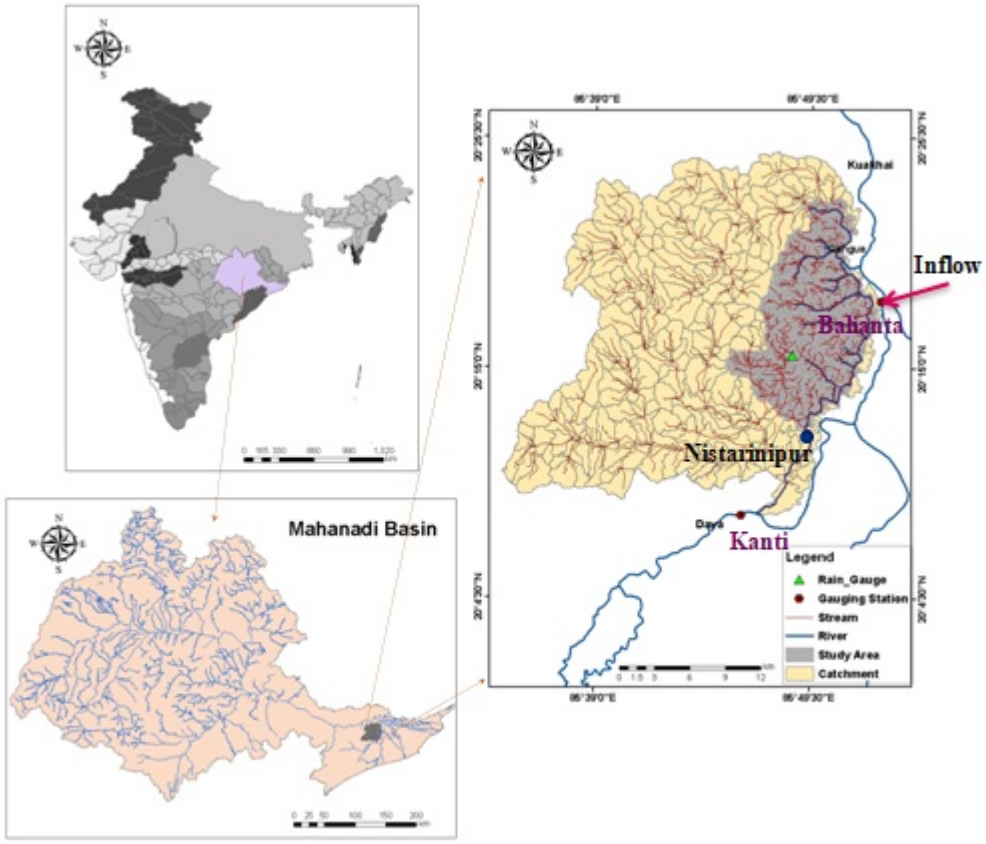

Fig. 1. Location of the Study Area

The stage at Kanti gauging station is calibrated and validated for monsoon periods of 2009, 2011 and 2014.

METHODOLOGY

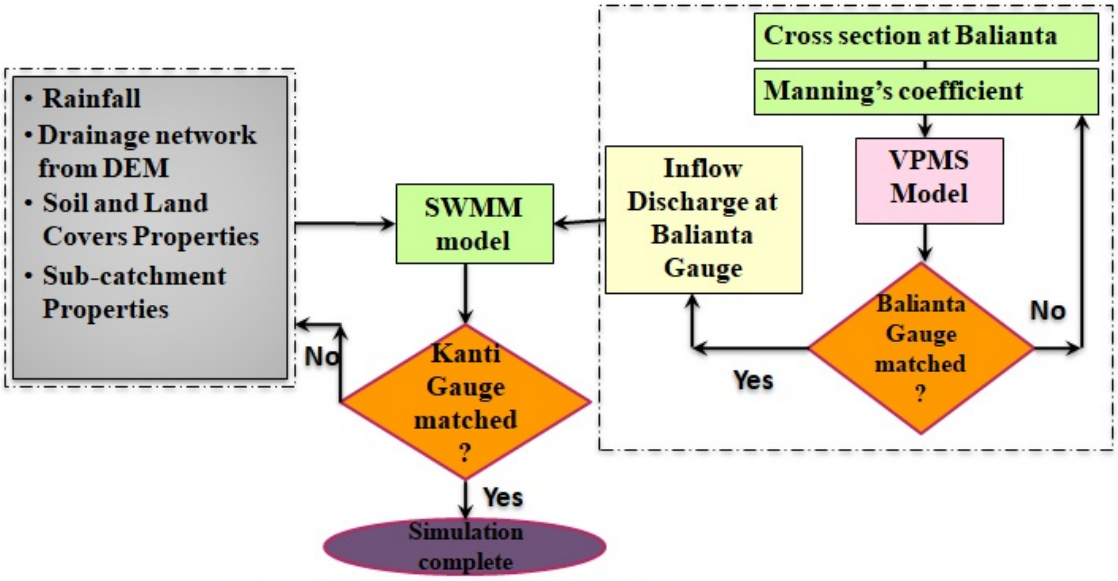

Fig. 2. Overview of the methodology.

Fig. 2 describes the overall framework of the study. The stage to discharge estimation was carried out at Balianta gauging station using the VPMS model (Perumal et al. 2010) as shown below.

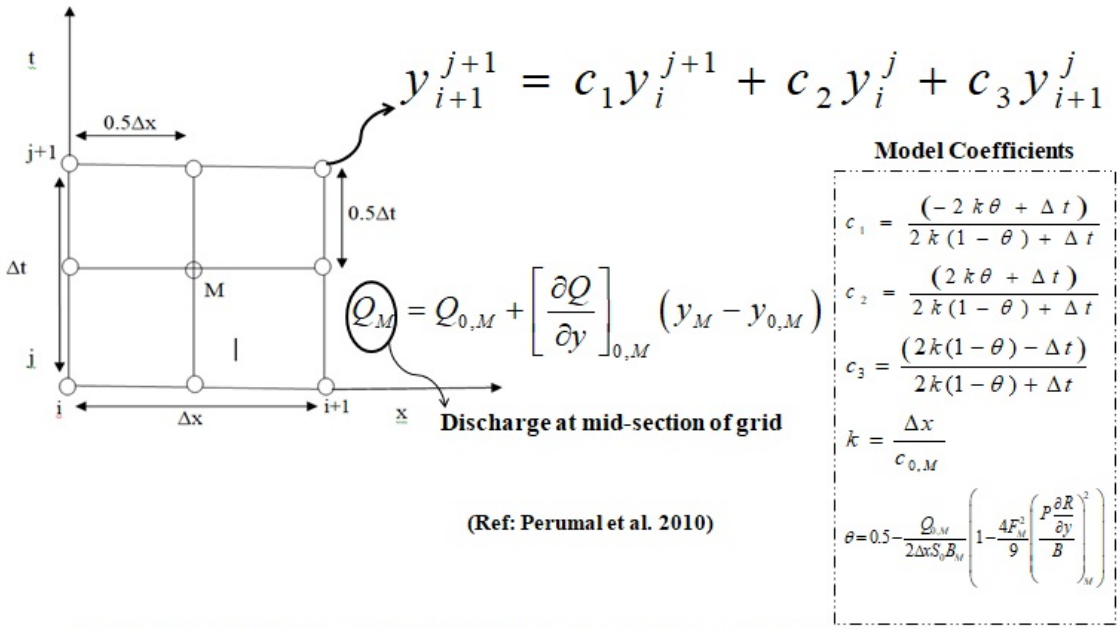

Fig. 3. Theoretical Background of the Variable Parameter Muskingum Stage (VPMS) model

RESULTS

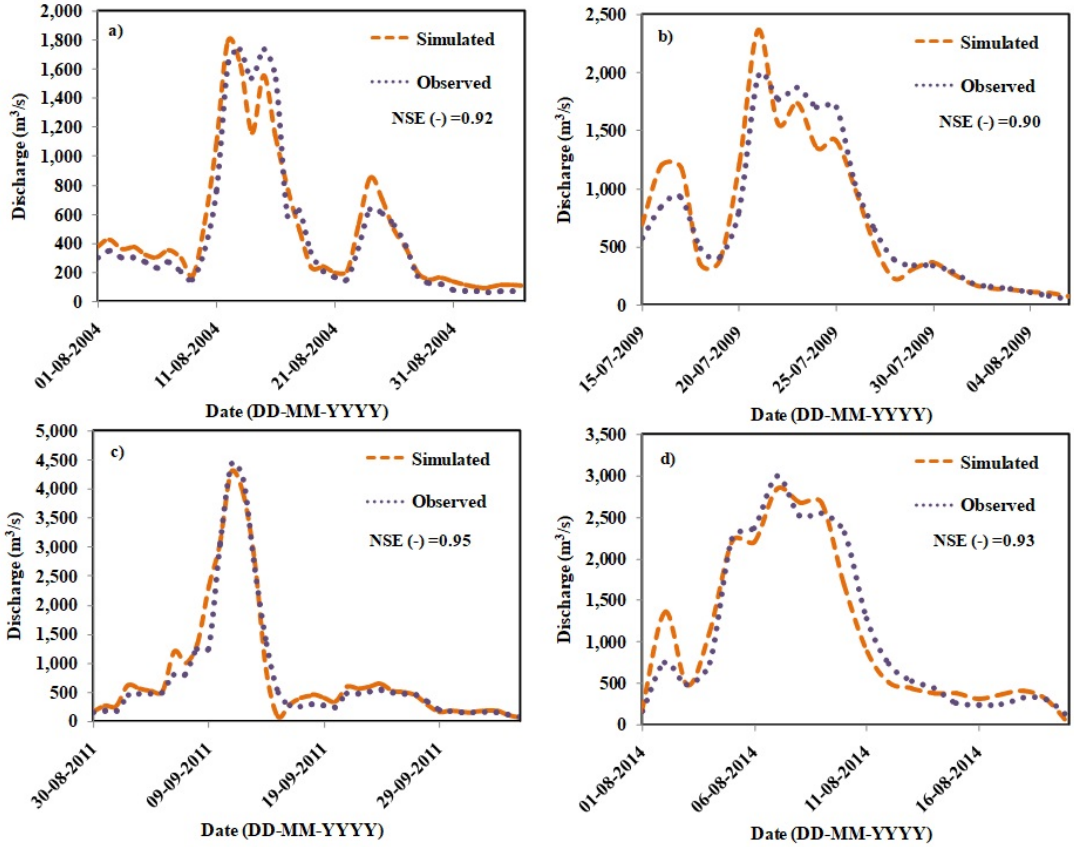

Fig 4. Streamflow reproduction by the VPMS model at Balianta gauging station for the calibration year of 2004 (a); and validation years of 2009, 2011, and 2014 (b-d).

The calibrated manning's coefficient value (0.028) in the VPMS model was used to find the discharge at Balianta gauging station corresponding to hourly stage data and input to the SWMM model for flow depth estimation at Kanti gauging station as shown below (Fig. 5).

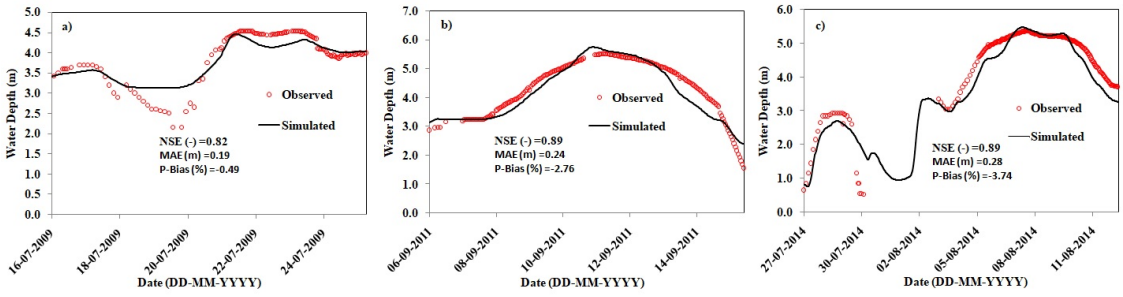

Fig. 5. Performance of SWMM-VPMS model at Kanti gauging station for the calibration years of 2009 (a); and validation years of 2011, and 2014 (b, c).

Fig. 5 shows good agreement between observed and simulated flow depth for 2009, 2011 and 2014 years at Kanti gauging station.

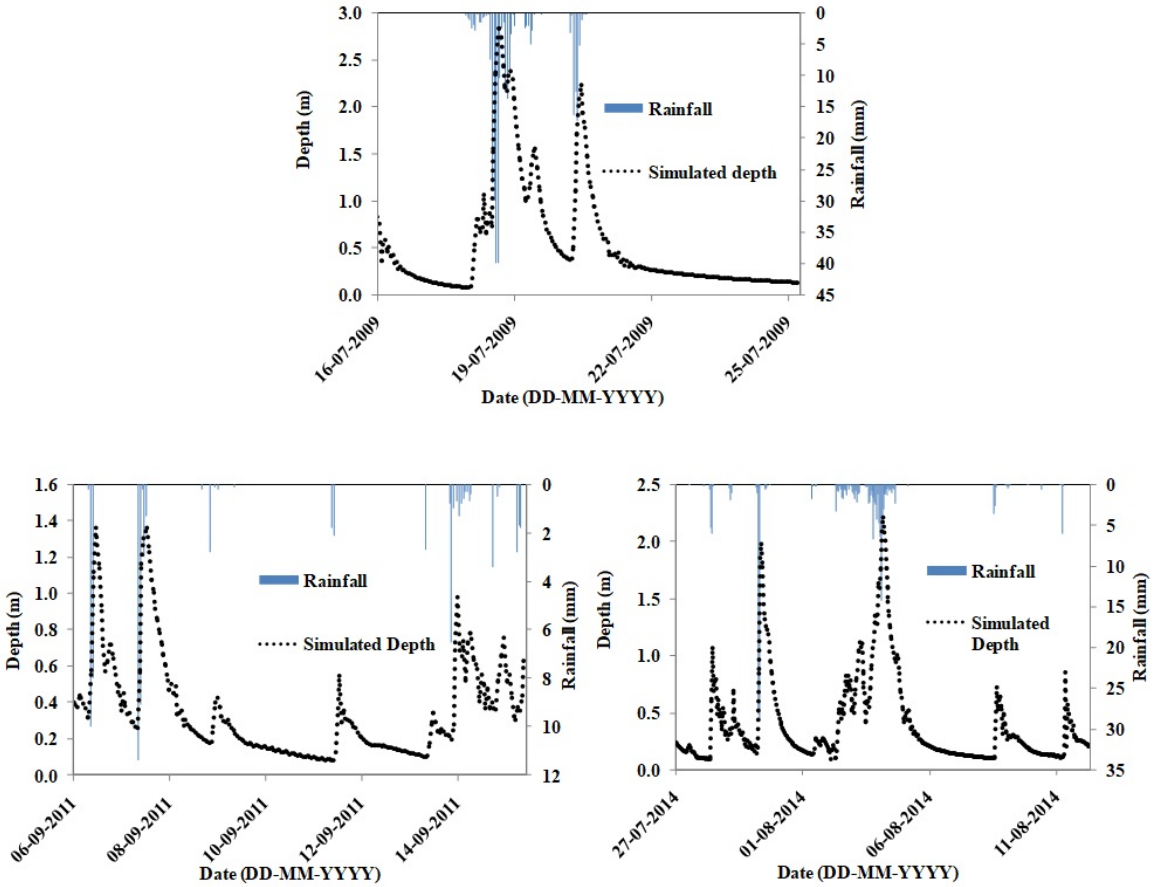

Fig. 6. Simulated flow depth at the Urban Outlet (Nistarinipur) for the years 2009, 2011, and 2014.

At Nistarinipur, the flow depth patterns seem to be in good agrrement with the rainfall.

The typical flooding situation can be seen well-simulated on drainage no. 10 (Fig. 7).

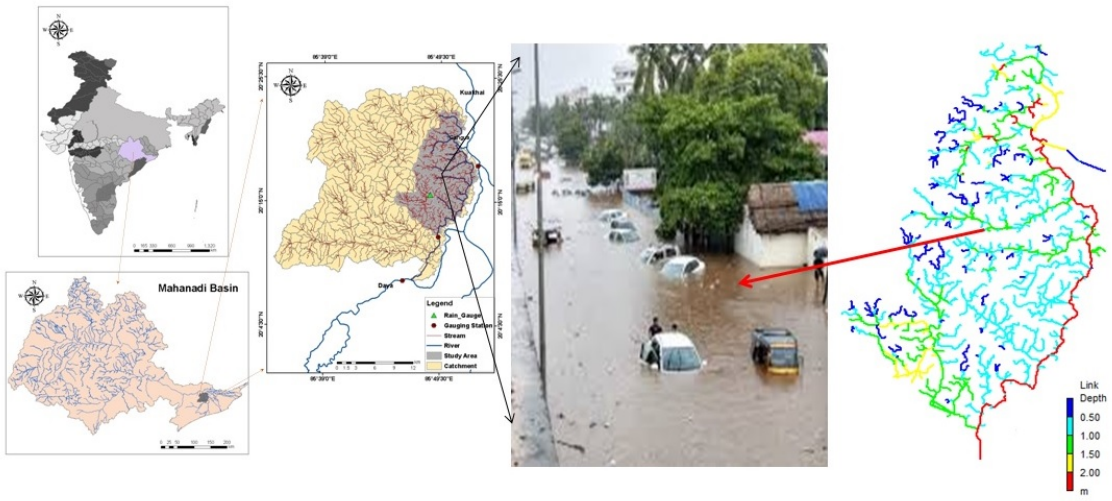

Fig. 7. Depiction of a typical flooding situation on drainage no. 10.

CONCLUSION

Conclusion

- **The VPMS model can be used effectively for discharge information extraction from stage.**
- **The proposed SWMM-VPMS model can be used for a catchment where the tributary is ungauged while the main river is gauged at downstream of the confluence point.**
- **The developed approach is capable of providing both stage and discharge information at any section, which can be used to get a preliminary idea on areas vulnerable to flooding.**

Acknowledgement

The authors are acknowledging CWC, BBSR and Hydrometry Dept., Govt. of Odisha for providing the data for the study. The authors also acknowledge the MHRD,India for providing fellowship to the first author.

DISCLOSURES

The authors declare that there is no conflict of interest.

ABSTRACT

Nowadays, many of the world cities and its peripheral areas are under constant threat of flooding due to high rainfall events. Increased rate of severe flood hazards world-wide have created a demand for understanding the flooding behaviour across various urban and peri-urban catchments. However, simulating the flooding scenarios under limited hydrological data condition is a great challenge for the urban water planners and managers, especially in developing countries. To this, in this study, a combined modelling approach is proposed with the physically based Variable Parameter Muskingum Stage (VPMS) routing model to develop a local rating curve for generating the discharge data from the available stream stage data, which was subsequently used as an input to the Storm Water Management Model (SWMM). The coupled methodology is applied in a typical ungauged urban and peri-urban catchment of eastern India. The proposed SWMM-VPMS model is calibrated for the monsoon (rainy) season of the years 2009, and validated for the monsoon seasons of 2011 and 2014. The performance of the model is satisfactory with the Nash-Sutcliffe efficiency (NSE) estimates of 0.82, 0.89, and 0.89 for the years 2009, 2011, and 2014, respectively. The proposed SWMM-VPMS model can be used for a catchment where the tributary is ungauged while the main river is gauged at a downstream location of the confluence point. This methodology can also be adopted in catchments with missing rating curves. Additionally, the information regarding spatial distribution of channel flow depth at different time can be utilized to have an initial assessment of the flood-vulnerable areas.

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