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Importance of Subdivision Resolution of Surrogate Models for Emulating Catchment Response and Surcharge

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Abstract
State-of-the-art urban drainage modelling applies high-fidelity physically based distributed models. However, high computational demands of such models limit the usage. In this study a conceptual surrogate model is set up to emulate the output of a Mike URBAN model. The surrogate model is a volume-based model, which models discharges from a user-defined compartment to downstream compartment(s) as well as to the surface. Training data is created by extracting steady state volume-discharge points from Mike URBAN and applying a piecewise linear interpolation between the points. Two surrogate models are set up for the Elster Creek catchment in Melbourne, Australia. The first consists of one compartment and the second subdivides this into 17 smaller compartments. Results show that both surrogate models perform very well in emulating the compartment volume and discharge from Mike URBAN. The surcharge is more difficult to model as its behaviour is more dynamic and hence most different from the steady state training data. Increasing compartment resolution shows an overall improvement of all results - especially in capturing surcharge behaviour. The results show that even surcharging urban drainage systems can be modelled sufficiently accurate for many purposes with the proposed surrogate models.

Keywords: Modelling resolution, Conceptual Modelling, Computation Time, Surcharging

1. INTRODUCTION

Due to climate change and urban development the need for fast and accurate urban drainage models are increasing. State-of-art models are high fidelity physically based distributed models such as Mike Urban (MU) and Mike Flood (MF). However, the usage of such models is limited due to large computation times. Many attempts have been made to reduce computational requirements while still assuring an accepting level of accuracy. Besides increasing the numerical efficiency of the computation by e.g. parallelization, cloud computing etc., this work can be divided in (i) simplified physically based models and (ii) conceptual models. (i) reduce the physical accuracy by e.g. simplifying the Saint-Venant equation or the computational grid e.g. Fewtrell et al. (2011). (ii) seek to model the desired response without including any of the original physical terms e.g. Wolfs et al. (2013). An example of the latter is a surrogate model (SM), which aims to emulate the output of a higher fidelity model. Hence, the output of the high-fidelity (HiFi) model is used to train and validate the surrogate model instead of observed data which may be unavailable.

This study aims to investigate the performance of a simple surrogate model which should be applicable for both planning and real time control usage in the urban drainage modelling context. The surrogate model will be varied in size to examine the influence.

2. MATERIALS AND METHODS

2.1 Conceptual model

The surrogate model is setup by lumping sections of a HiFi model into compartments. The volume of water within each compartment is modelled as a simple mass balance of the in- and outgoing discharges. The outgoing discharges are governed by unambiguous volume-discharge rating curves which accounts for non-linearity's in the system. The SM engine applied is presented in Borup et al. (2017) with the difference that water can surcharge to the surface. In Figure 1 compartment *b* receives water from an upstream compartment, $Q_{in,b}$, and from rainfall runoff, $Q_{run,b}$. From here the water can be discharged downstream to compartment *c* and it can surcharge to the surface, $Q_{spill,b}$. Discharge to the surface and to downstream compartments are modelled in the same way and are unidirectional.

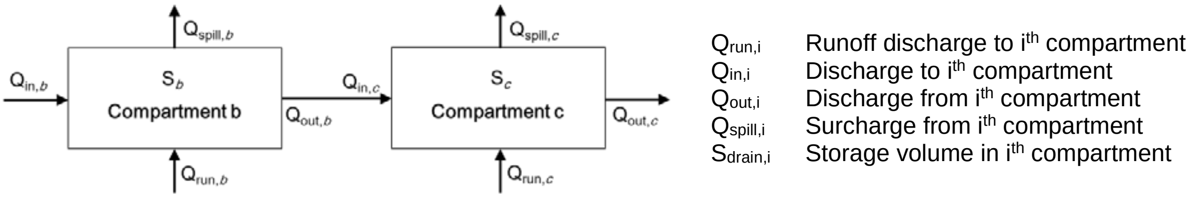

Figure 1. Conceptual setup for an example of a surrogate model containing two compartments, a and b.

2.2 Training and validation data

The governing volume-discharge relationships are derived from MU model results. For achieving a simple set of training data, steady state data are computed for a range of different rain intensities. The model is run with rain intensities ranging from 0 to 10 µm/s. Each intensity level is kept constant for four hours to ensure close to steady state in the system. Afterwards steady state volume and discharge values are extracted for each compartment and used as parameters for the SM. The SM then interpolates linearly between these points when it simulates discharges. For the validation data a rain series covering the period 1979-2015 from Melbourne is applied (Bureau of Meteorology, 2015). From here 3 x 15 events covering the largest depth, intensity over 30 min and 180 min are extracted.

2.3 Case study

The case study area is the Elster Creek Catchment located in Melbourne, Australia. A Mike Urban model of the area is provided and shown in Figure 2 left (Davidsen et al., 2017).

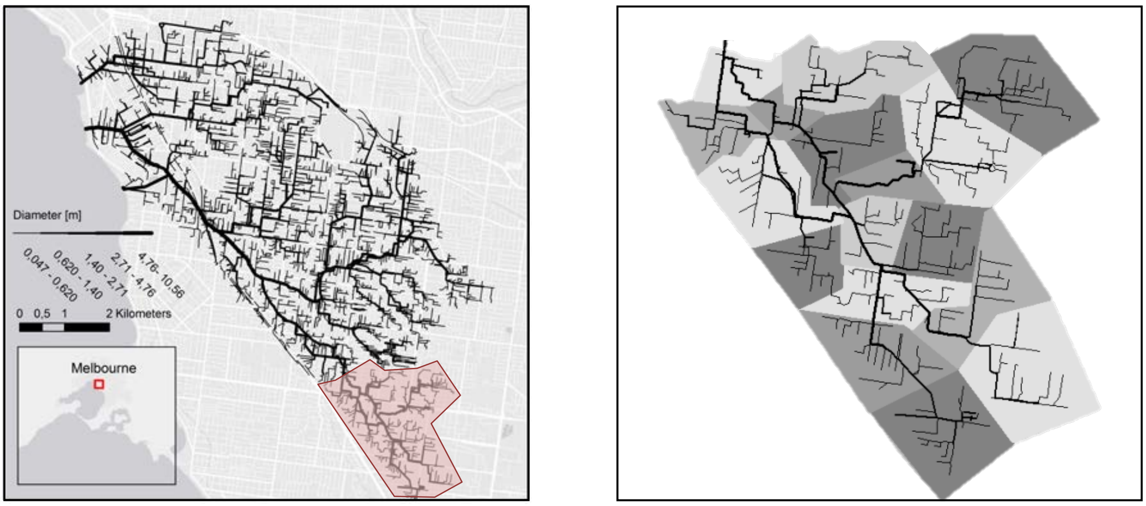

Figure 2. Elster Creek Catchment. Figure left shows compartment SM1 and right shows compartments $SM1_{div}$.

We will focus on the most upstream part of the catchment marked in the figure to the left. This area will be lumped to one compartment, SM1. To examine the influence of compartment resolution we subdivide this compartment further into 17 small compartments shown in Figure 2 to the right. Results from these compartments will be noted $SM1_{div}$.

3. RESULTS AND DISCUSSION

Figure 3 shows the MU model and the two SMs for an extracted rain event. The pink band shows the margin of MU when the discharge is varied with ±23% corresponding to the overall uncertainty of pipe discharge according to Hansen and Liu (2004).

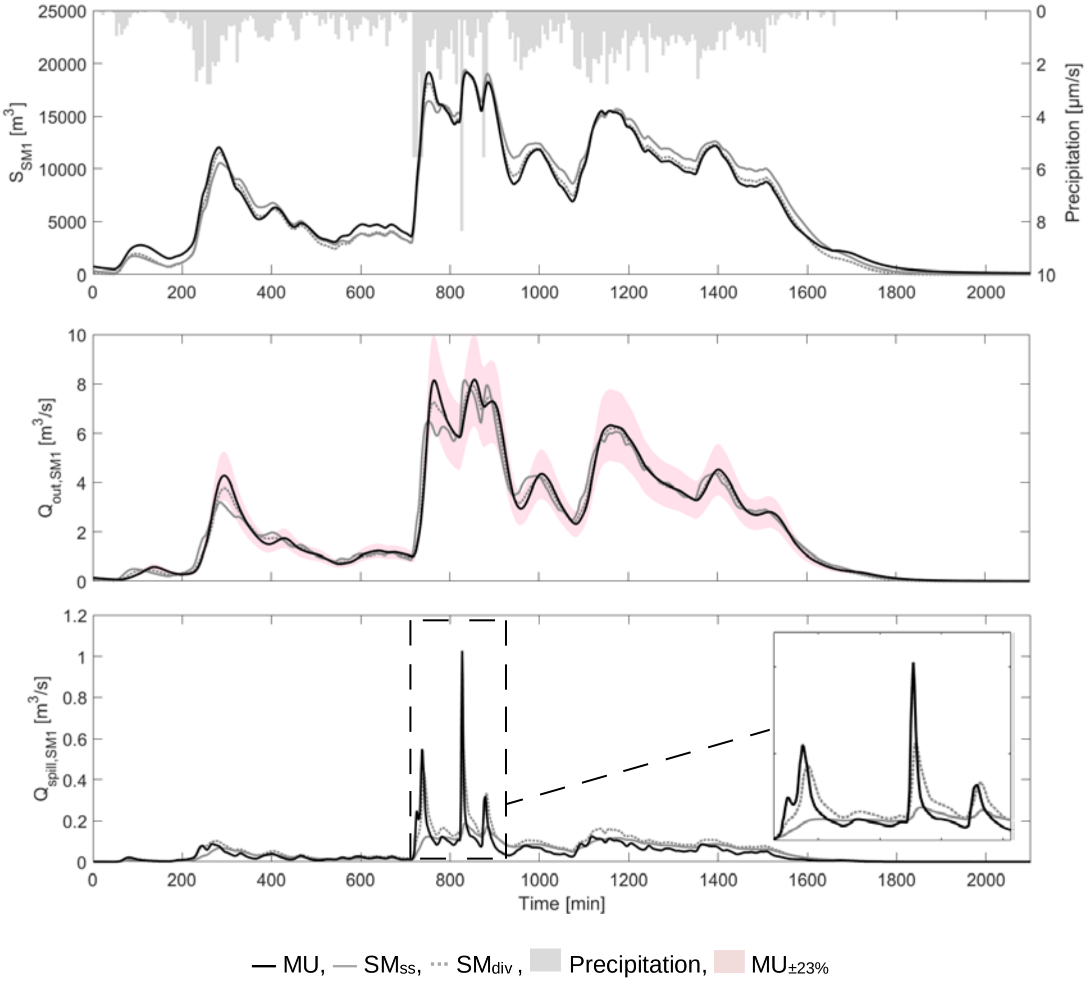

Figure 3. Comparison of Mike Urban model with surrogate model SM1 and surrogate model $SM1_{div}$.

Both SMs fit very well to the MU model for the volume and discharge, but an overall better fit is obtained when subdividing the compartments. Both SMs discharge are mostly within the MU uncertainty band. The behaviour of the surcharging is more difficult to emulate, which demonstrates the limitations of applying steady state training data to describe a dynamic process. However, it is seen that by subdividing the single compartment to multiple compartments a much better fit is obtained.

NSE (Nash-Sutcliffe-Efficiency), PEP (Peak-Error-Percentage) and PDIFF (peak difference in time) presented in Bennett et al. (2013) is used to evaluate the performance of the surrogate models for all 15x3 events. Results can be seen in Table 1. The results confirm the visual inspection. The overall performance of both surrogate models is very good with NSE values above 0.9 for volume and discharge, while for surcharging it is 0.620 for SM1. When subdividing the surrogate model to $SM1_{div}$ the NSE value is improved to 0.837. This improvement can also be seen in PEP, where the error is overall reduced. For surcharging it is reduced most from 24.9% to -1.57%. Since PEP is negative for $SM1_{div}$ the model generally overestimates the peaks while SM1 underestimates as also seen in Figure 3. Furthermore, timing of the surcharge peak is improved from -8.15 min for SM1 to 3.76 minutes for $SM1_{div}$. Computation time was reduced approximately 700,000 times for the surrogate model.

Table 1. Measures of performance for the two surrogate models.

	NSE [-]			PEP Mean / Median [%]			PDIFF [min]
	S	Q_{out}	Q_{spill}	S	Q_{out}	Q_{spill}	Q_{spill}
SM1	0.978	0.948	0.620	4.30 / 2.06	7.62 / 4.26	24.9 / 23.7	-8.15
$SM1_{div}$	0.991	0.990	0.837	0.823 / 0.810	5.79 / 4.30	-1.57 / -2.04	-3.76

CONCLUSIONS

Two simple surrogate models with different compartment resolutions were set up for Elster Creek catchment in Melbourne, Australia. Both models were able to sufficiently accurate emulate the volumes and discharges from a high-fidelity Mike URBAN model. The surcharge was more difficult to mimic as this is a more dynamic process and only steady state data was used for training. Subdividing the surrogate model achieved an overall improvement especially regarding surcharging. This study shows the great potential of surrogate models for further use in urban drainage modelling – even for surcharging systems.

Acknowledgement

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References

Bennett, N.D., Croke, B.F.W., Guariso, G., Guillaume, J.H.A., Hamilton, S.H., Jakeman, A.J., Marsili-Libelli, S., Newham, L.T.H., Norton, J.P., Perrin, C., Pierce, S.A., Robson, B., Seppelt, R., Voinov, A.A., Fath, B.D., Andreassian, V., 2013. Characterising performance of environmental models. Env. Mod. Softw. 40, 1–20.

Borup, M., Thrysøe, C., Arnbjerg-Nielsen, K., Righetti, F., Mikkelsen, P.S., 2017. A fast surrogate model tailor-made for real time control. 14th IWA/IAHR Int. Conf. Urban Drain.

Bureau of Meteorology, 2015. Rain data extracted from eWater MUSIC for Melbourne Australia.

Davidsen, S., Löwe, R., Thrysøe, C., Arnbjerg-Nielsen, K., 2017. Simplification of one-dimensional hydraulic networks by automated processes evaluated on 1D/2D deterministic flood models. J. Hydroinf 19, 686–700.

Fewtrell, T.J., Duncan, A., Sampson, C.C., Neal, J.C., Bates, P.D., 2011. Benchmarking urban flood models of varying complexity and scale using high resolution terrestrial LiDAR data. Phys. Chem. Earth 36, 281–291.

Hansen, A. C. & Liu, L. 2004 Risk-Based Design of Drainage Systems Uncertainty Analysis. Master's thesis, Technical University of Denmark, Kongens Lyngby, Denmark.

Wolfs, V., Villazon, M.F., Willems, P., 2013. Development of a semi-automated model identification and calibration tool for conceptual modelling of sewer systems. Wat Sci. Tech. 68, 167.