Summary MSc Thesis Rizky Moes: Modelling Peak Flow at 10-minutes Resolution in the Upper Ciliwung Catchment, Indonesia

The Indonesian capital city of Jakarta is a typical delta city suffering from regular riverine flooding (Figure 1), usually in the peak of the wet season (November to January). One of the causes is the still ongoing structural increase of the peak discharge intensity of the rivers crossing the city due to land use change in the upstream parts of the catchments, steep mountainous areas (±3000m +MSL) in the south of Java island.

Figure 1. The outlet of the Upper Ciliwung River at the Katulampa weir (for location see Figure 2), south of Bogor city, West Java, Indonesia in January 2014. (left picture, source: https://commons.wikimedia.org/wiki/File:Bendung_Katulampa_Januari_2014.jpg) Peak flow as observed here could arrive in the city of Jakarta in about half a day, causing severe flooding. (right picture, source https://www.flickr.com/photos/budiwins/8391569698)

The Ciliwung is the largest of several rivers and the upstream part of the catchment, the Upper Ciliwung (160 km^2) was used as study area. Many modelling studies already have shown the negative effect of land use change, especially deforestation, which led to increased peak discharges at the outlet of the Upper Ciliwung, the Katulampa weir, about 30 km south of the border of the city of Jakarta. So far modelling studies in the Upper Ciliwung were only done at low temporal resolution (day-month time step), much coarser than the timescale of observed rainfall-runoff processes in the study area (<2 hours, see figure 2)

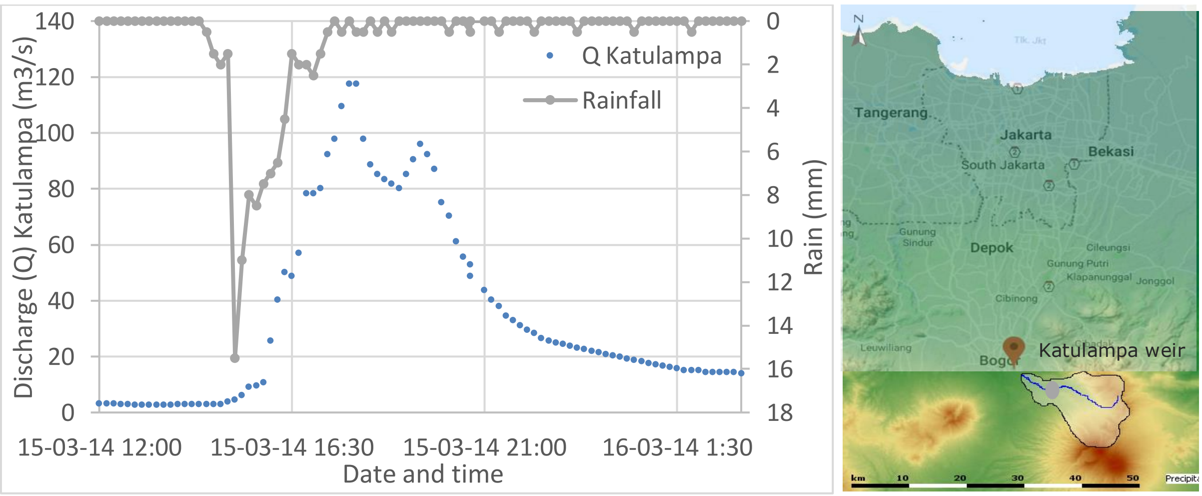

Figure 2. Hydrograph of a rainfall event in March 2014 at Katulampa (location indicated in red on the right figure). Observations were measured at 10-minutes interval in the Upper Ciliwung catchment (black bordered polygon). Grey dot on the right figure indicate the location of the rain gauge.

The objectives of this study were to explore the possibilities of high frequency rainfall-runoff measurements for two applications: more accurate event based peak flow modelling and simulation of land use change effects on peak discharges in the Upper Ciliwung Catchment. The fully distributed wflow_sbm model was used for the discharge simulations.

The model was calibrated on two different peak discharge events using rainfall-runoff data measured at 10-minutes interval. Based on adjusted NSE values (NSE_{adj} up to 0.87) and visual comparisons of the hydrographs of the simulated discharge (Q_{sim}) with the observed discharge (Q_{obs}), wflow_sbm showed promising results of the prediction of peak discharge at average rainfall amounts (<30 mm/h), but only for dry initial catchment conditions (~ 0 m^3/s base flow and >3 days without rainfall, see Figure 3).

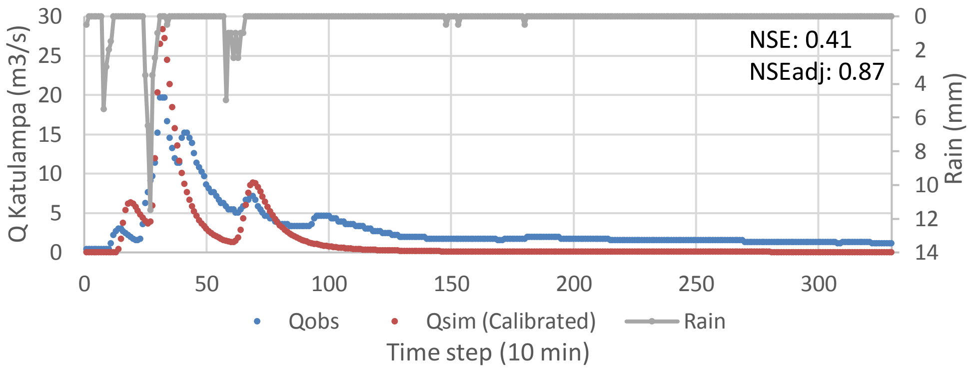

Figure 3. wflow_sbm model calibration result (in red) for an event in dry initial catchment conditions.

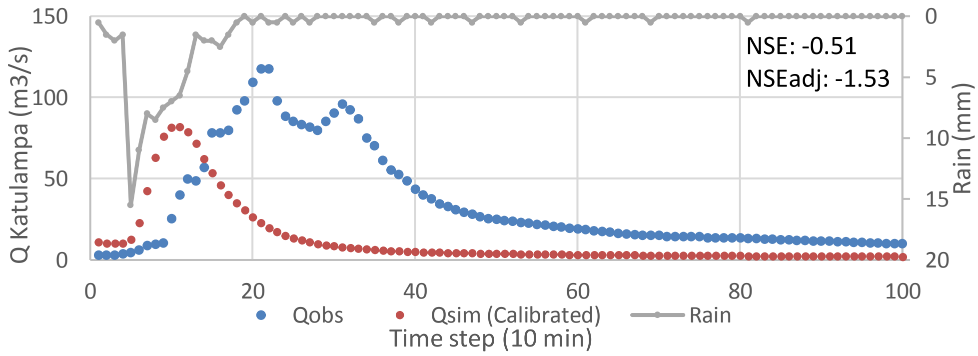

Figure 4. wflow_sbm model calibration result (in red) for an event in wet initial catchment conditions.

This model is in its current state unsuitable for flood risk prediction as it was not possible to simulate continuous high base flow at wet initial conditions or for relatively high rainfall input (>30 mm/h, see Figure 4). Furthermore, it was shown that extrapolation of rainfall data from the only point which had observations at 10-minutes interval situated in the west part of the catchment (Figure 2), was insufficient to give an accurate indication of the exact amount of water entering the Upper Ciliwung catchment. This caused for most events unrealistic simulated runoff patterns, either mistimed or wrong in magnitude with respect to Q_{obs}, causing difficulties in evaluating the exact model performance at this high temporal resolution. Given the fact that the dynamics of the discharge signal are well simulated for dry initial conditions (Figure 3) and assumed that Q_{sim} resembles reality to a certain extent, the scenario analysis revealed that peak discharges could already decrease by up to 18% for a small reforestation project (<2km^2) in the west of the catchment. The theoretical increase of the total peak discharge volume caused by a unit area of added built up space could be compensated by twice the unit area of added forest.

To enable high temporal resolution modelling, placing 1 or 2 extra rain gauges in the Upper Ciliwung catchment and a monitoring scheme at 10-minutes interval at all (existing) gauging stations, especially in the wet season, are recommended. Using a decent interpolation technique such as regression Kriging, the high spatial and temporal variation of an (extreme) rainfall event can be captured in more detail and can eventually be used as model input for a better (real-time) prediction of the timing and magnitude of peak discharges at Katulampa. If all modelling challenges are resolved, a distributed model like wflow_sbm, is highly recommended as tool for further research to accurately predict peak flow in a steep catchment like the Upper Ciliwung. It is also strongly advised to do further research to the impact of reforestation at high temporal and spatial resolution during peak flow conditions, which was not possible using wflow_sbm in this study.

All conclusions and recommendations coming forward in this thesis report should be taken with care as not the full catchment dynamics were explored due to data scarcity and model limitations, but do have implications for flood risk mitigation for the city of Jakarta and cities situated in similar catchments around the world.

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