CONTINUOUS HYDROLOGICAL MODELING USING SOIL MOISTURE ACCOUNTING FOR WATER RESOURCES ASSESSMENT IN KELANI RIVER BASIN, SRI LANKA

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Degree of Master of Science

Department of Civil Engineering

University of Moratuwa
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May 2018

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Thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Water Resources Engineering and Management

Supervised by
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Sri Lanka

May 2018

DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Mohammad Najim Nasimi Date

The above candidate has carried out research for the Master’s thesis under my supervision.

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Dr. R. L. H. L. Rajapakse Date

Continuous Hydrological Modelling Using Soil Moisture Accounting for Water Resources Assessment in the Kelani River Basin, Sri Lanka

ABSTRACT

The assessment of water resources in a river basin for fulfilling various needs in the present and future requires a proper estimation of water availability. This is possible through hydrological modelling. The Kelani river basin in Sri Lanka experiences water stress under the current water uses, development, and urbanization effects. It requires a continuous hydrological model for the assessment of its water resources, focusing on impending climate change impacts. Continuous hydrological models, unlike event-based models, simulate longer periods that include both dry and wet conditions. Soil moisture accounting (SMA) model in the Hydrologic Engineering Centre-Hydrologic Modelling System (HEC-HMS) is chosen to simulate the streamflow. However, the SMA loss model requires precise and updated soil and land use data for parameter estimation, which is not available for the study area. In addition, the lumped nature of the model comparing to distributed models is also in question. This research discusses the development, parametrization and calibration methodologies for the 14 parameters of the HEC-HMS model with the SMA algorithm by considering a catchment divided into several sub-catchments. This division is based on the maximum drainage area method to improve the model accuracy in a scarce soil data situation.

The SMA loss model requires 14 parameters to be set. Among these, the impervious percentage is calculated from a land use map; the groundwater 1 and 2 storage as well as the groundwater 1 and 2 coefficients are calculated through the streamflow recession analysis. The maximum infiltration, soil storage, tension storage, and soil percolation rate are calculated from the similar studies; and the groundwater 1 and 2 percolation with four initial parameters are calculated only through a calibration procedure. The model is calibrated using daily data from 2007 to 2012 and validated from 2012 to 2017. The mean ratio of absolute error (MRAE) is used as a primary objective function. The coefficient of determination (R^2), percent volume error (PVE), and Nash-Sutcliffe efficiency (NSE) are also used to compare and evaluate the model performance.

The results indicate that the performance of the rainfall-runoff model significantly improves when the basin is subdivided into three to eight sub-catchments and the optimum result is found with the five sub-catchments. For the calibration period, the performance of the model is adequate with a R^2 of 0.83, a NSE of 0.82, a PVE of 5.3%, and a MRAE = of 0.38. Similarly, adequate results are also retrieved for the validation period, with a R^2 of 0.81, a NSE of 0.80, a PVE of 13.1%, and a MRAE of 0.36. The results of the statistical analysis indicate that the simulated and observed flows are reasonably well correlated. The parameter analysis shows that the soil percolation and tension zone storage rates are the most sensitive and second storage of ground water (GW2) is the least sensitive parameters. Furthermore, for the Kelani river basin up to the Hanwella catchment, the simple surface, simple canopy, ModClark, recession and Muskingum methods are found to be the most suitable methods alongside the SMA model.

The model performance can potentially be improved through further calibration using hourly climatic input data instead of daily data and with using multiple gauging stations instead of single gauge station. In the future, the validated HEC-HMS model can be employed with seasonal climate forecasts under long-range land use and climate projections. Besides, radar-based precipitation data can be used to represent the climatic variability on a grid-based scale.

Keywords: Multi sub-catchment comparison, SMA parameter estimation, soil scarcity situation, watershed subdivision

DEDICATION

Every challenging work needs self-effort as well as the guidance of elders especially those who are very close to our heart.

My humble efforts are dedicated to my sweet and loving

father & mother

whose affection, love, encouragement, and prayers of each day and night allowed me to accomplish this success and honour.

Along with the above, this work is also dedicated to my committed and respected

teachers

ACKNOWLEDGEMENTS

First and above all, I praise Allah, the Almighty for providing me with this opportunity and granting me the capability to proceed successfully.

I want to express my sincere gratitude to my research supervisor, Dr. R.L.H. Lalith Rajapakse for his continuous support of my study, his patience, motivation, and immense knowledge. Without his dedicated supervision and continued guidance, this thesis would not have been in a success. I am truly grateful to him for spending his valuable time with me working towards completing this research. He consistency ensured that this research was my own work by steering me in the right direction whenever I deviated.

I will never hesitate to convey my thanks to the Professor N.T.S. Wijesekera for extending all necessary help. He was kind enough to provide help and support even with his busy schedule. His sincere and consistent encouragement is greatly appreciated.

I take this opportunity to express gratitude to all members of the Department of Civil Engineering for their help and support. I place on record my sincere thanks to the South Asia Foundation for providing me with a scholarship to pursue a master’s degree in Water Resources Engineering and Management. I would like to thank my mentor, Mr. H.W. Kumarasinghe, for his kind assistance during my stay in Sri Lanka.

Finally, I must express my very profound gratitude to my parents for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

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