UNIVERSITI PUTRA MALAYSIA

UNCERTAINTY ANALYSIS OF EXTREME HYDROLOGICAL EVENTS IN THE SEMI-ARID ZAYANDEROOD BASIN, CENTRAL IRAN

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By

MAJID MIRZAEI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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Dedication

This work is dedicated to my parents

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman: Professor Ir. Lee Teang Shui, PhD

Faculty: Engineering

Stream flow, which is a part of the integrated process of atmospheric and topographic processes, is of prime importance to water resources planning. Hydrologic simulation models for stream flow have implicit uncertainty in their handling of processes. Uncertainty may occur during data collection, modeling, and analysis of the engineering system and model predictions. Common methods for stream flow forecasting use historical discharge data series at some reach of the river in the watershed. It is universally believed that climate and landuse change can affect the spatial and temporal distribution of water resources and also change hydrological parameters such as intensities and frequencies of extreme hydrological events. Distributed watershed models are increasingly being used to support decisions about alternative management strategies in the areas of land use change and climate change. In this study, the kinematic runoff and erosion model KINEROS2 which is an event

oriented, physically based model was used for rainfall-runoff simulation. The main objective of this study is to investigate the effects of uncertainty in rainfall and models input parameters for extreme events in a semi-arid region and quantifying the uncertainties in frequency analysis of extreme rainfall events which are associated with Depth Duration Frequency (DDF) curves. The calibration scheme is carried out under the Generalized Likelihood Uncertainty Estimation (GLUE) framework to quantify uncertainty in the rainfall-runoff modelling process. These uncertainties are presented in the rainfall-runoff modeling for investigation of uncertainty effects in discharge and volumes of extreme hydrological events and subsequently embedded into guidelines for risk based design and management of urban water infrastructure.

The uncertainty in the rainfall input data was studied using the rainfall data of 16 gauging stations in the Zayanderood basin, central Iran. The 36 rainfall series were generated based on rainfall at each of the gauging stations. Statistical evaluations for stream flow prediction indicate that there is good agreement between the measured and simulated flows with Nash Sutcliffe values of efficiency of 0.85 and 0.79 for calibration and validation periods respectively. Uncertainty analysis was carried out on the new distribution of input parameters and various duration and frequency of rainfall for extreme events are considered. The watershed was simulated for each event using Monte Carlo sampling from statistical distribution of input parameters. Uncertainty analysis applied to the hydrologic model indicated that uncertainty in input parameters affects the results significantly. The uncertainty in output is expressed through peak discharge values and stream flow volumes. For peak discharges the amounts of upper uncertainty is reduced with increasing rainfall duration, for all return periods. Maximum reduction was with the return period of 100

years that was reduced from 1327m^3/s for 24 hour rainfall duration to 582m^3/s for 120 hours rainfall duration. By increasing rainfall duration, the difference between upper limit of uncertainty and predicted value declines. In fact, model accuracy in discharge calculation increases with rainfall duration. However for stream volumes, the variation of upper uncertainty band does not have a recognizable trend with increased rainfall duration for all return periods. The difference between upper limit of uncertainty and predicted values is significant for all return periods and rainfall durations. This difference slightly increases with increase of rainfall duration for all return periods. The validated KINEROS2 model enables predicting streamflow volume for extreme events with reliable accuracy without uncertainty analysis. The findings pointed out that extreme discharges prediction should not be static tools but instead should undergo continuous adaptation with uncertainty analysis, relative to possible changes in watershed hydrology.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

ANALISIS KETIDAKPASTIAN PERISTIWA HIDROLOGI LAMPAU DI LEMBANGAN SEPARA GERSANG ZAYANDEROOD, IRAN TENGAH

oleh

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Mai 2012

Pengerusi: **Profesor Ir. Lee Teang Shui, PhD**

Fakulti: **Kejuruteraan**

Aliran sungai, sebahagian proses sepadu proses atmosfera dan proses topografi, penting kepada perancangan sumber air. Model penyelakuan hidrologi untuk aliran sungai berketidakpastian tersirat dalam prosesnya, ketidakpastian yang mana boleh berlaku semasa proses pengumpulan data, pemodelan, dan analisis ramalan model sistem kejuruteraan. Kaedah biasa untuk ramalan aliran sungai menggunakan sejarah data aliran pada sebahagian sungai di dalam lembangan. Adalah dipercayai semestanya bahawa perubahan iklim dan kegunaan tanah berpengaruh terhadap pengedaran ruang dan masa sumber air serta juga mengubah parameter hidrologi selain daripada keamatan dan kekerapan peristiwa hidrologi melampau. Model teragih legeh semakin banyak diguna demi menyokong keputusan strategi pengurusan pilihan di kawasan kegunaan tanah berubah dan iklim berubah. Dalam kajian ini, air larian kinematik dan model hakisan KINEROS2 sebagai model yang berasas fizikal dan

terperistiwa guna untuk perselakuan hujan-air larian. Kajian ini bertujuan menyiasat kesan ketidakpastian berkaitan hujan dan ketidakpastian parameter input model hidrologi peristiwa melampau di kawasan separa gersang dan menilaikan ketidakpastian dalam analisis kekerapan peristiwa hujan melampau yang berkaitan dengan lengkung Dalaman-Jangkamasa-Kekerapan. Skema tentukur yang dilangsungkan bawah rangkaian Anggapan Ketidakpastian Kebolehjadian Umum untuk menilaikan ketidakpastian dalam proses permodelam hujan-air larian. Ketidakpastian kemudian dipakai dalam permodelan hujan-air larian untuk menyiasat kesan ketidakpastian keatas aliran dan isipadu peristiwa hidrologi melampau dan berikutannya dimasuk ke dalam garispanduan untuk rekabentuk berdasar risiko dan pengurusan infrastruktur air bandar.

Ketidakpastian data input hujan dikaji menggunakan data hujan sebanyak 16 stesyen ukuran di Lembangan Zayanderood, Pusat Iran. 36 siri hujan dijana berdasarkan hujan di setiap stesyen ukuran. Penilaian statistik untuk ramalan aliran sungai menunjuk bahawa ujudnya bandingan keputusan baik di antara aliran yang diukur dan yang terselaku dengan nilai kecekapan Nash Sutcliffe sebanyak 0.85 dan 0.79 untuk penentukuran dan pengesahan masing masing. Analisis ketidakpastian dibuat ke atas pengedaran baru parameter input dan berbagai jangkamasa dan kekerapan hujan peristiwa melampau dikaji. Legeh itu diselaku bagi setiap peristiwa mengguna pengsampelan Monte Carlo daripada pengedaran statistik parameter input. Analisis ketidakpastian dibuat keatas model hidrologi menggambarkan bahawa ketidakpastian parameter input berkaitan berkesan ke atas keputusan. Ketidakpastian dalam hasil dihuraikan melalui nilai aliran kemuncak dan isipadu aliran sungai. Bagi aliran kemuncak banyaknya ketidakpastian had teratas dikurangkan berkadar dengan naik jangkamasa hujan untuk semua kala kembali. Penurunan maksimum berlaku untuk kala kembali 100 tahun di mana ianya dikurangkan daripada 1327 m^3/s bagi 24 jam jangakmasa hujan ke 582 m^3/s bagi 120 jam jangkamasa hujan. Dengan tambahan jangkamasa hujan maka perbezaan di antara had teratas ketidakpastian dan nilai diramalkan turun, bahkan kejituan model dalam kiraan aliran bertambah dengan tambahan jangka masa hujan. Akan tetapi, bagi isipadu sungai, perubahan jalur had atas ketidakpastian tidak bersifat jelas tren bagi tambahan jangkamasa hujan untuk semua kala kembali. Perbezaan diantara had teratas dan nilai diramalkan bermakna bagi semua kala kembali dan jangkamasa hujan. Perbezaan ini bertambah sedikit sekadar dengan tambahan jangkamasa hujan bagi semua kala kembali. Model tersebut membolehkan ramalan isipadu sungai untuk peristiwa melampau dengan kejituan bolehharap tanpa analisis ketidakpastian. Keputusan menggambarkan bahawa ramalan aliran melampau tidak saja sebagai alat statik bahkan sebaliknya diubahsuai berterusan dengan analisis sekadar dengan segala perubahan boleh di dalam hidrogi legeh.

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APPROVAL

I certify that an examination committee has met on date of viva to conduct the final examination of Majid Mirzaei on his Doctor of Philosophy thesis entitled "Uncertainty

Analysis of Extreme Hydrological Events in The Semi-Arid Zayanderood Basin, Central Iran" in accordance with Universiti Pertanian Malaysia (higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination committee are as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for equations and citations, which have been duly acknowledged. I also declare that it has not been previously and is not currently submitted for any other degree at Universiti Putra Malaysia or other institutions.

MAJID MIRZAEI

Date: 28 May 2012

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