UNIVERSITI PUTRA MALAYSIA

CALIBRATION AND EVALUATION OF A FLOOD FORECASTING MODEL (MODIFIED TANK MODEL) FOR KELANTAN RIVER BASIN

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CALIBRATION AND EVALUATION OF A FLOOD FORECASTING MODEL (MODIFIED TANK MODEL) FOR KELANTAN RIVER BASIN

By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

CALIBRATION AND EVALUATION OF A FLOOD FORECASTING MODEL (MODIFIED TANK MODEL) FOR KELANTAN RIVER BASIN

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Chairman: Abdul Halim Ghazali

Faculty: Engineering

A distributed lumped conceptual flood forecasting model, namely Modified Tank Model was calibrated in this study for the Kelantan River Basin (12056 km^2). Six hours rainfall and flood level data were collected from DID Data Bank and compiled as an input to Modified Tank Model. Autoregressive corrections were implemented to improve the simulated flood level at Guillemard Bridge (forecasting station). Statistical method and objective functions were applied to evaluate the simulation and forecasting capability of the Modified Tank Model.

Four years of flood data (1990, 1991, 1992 and 1994) were used to calibrate the Modified Tank Model and the performance of the model was verified by using 1998 data. A set of tank coefficients that suit tank configuration selected for Kelantan River Basin were determined by trial and error calibrations. Flood levels at Guillemard Bridge were simulated with actual measured catchment rainfall and the Mean Absolute Error (MAE) was found to be 0.59 m (7.8%) and $R^2 > 0.81$. The Modified Tank Model was found to be able to simulate and forecast the rising limb of flood hydrograph as well as the runoff

peak for 6hr, 12hr, 18hr and 24hr lead time forecasts. Good correlation ($R^2 > 0.97$) and average absolute error of 0.16 m were found for the 6hr lead time forecast (with error adjustment module). While average absolute errors of 0.2 m (2.6%), 0.24 m (3.1%) and 0.28 m (3.8%) were obtained for the 12hr, 18hr and 24hr forecasts with their R^2 within the range of 0.96 and 0.97.

The accuracy of water level forecast depends on the accuracy of the future rainfall forecast. In this study, two assumptions on rainfall quantities were made in order to evaluate the forecasting capability of the Modified Tank Model in actual forecasting operation. First assumption (Case A), assuming similar rainfall persists for the next 24 hours gives a range of errors from 0.26 m - 0.36 m, 0.36 m – 0.49 m and 0.45 m – 0.59 m with respect to 12hr, 18hr and 24hr lead time forecast while errors of the second assumption (Case B), assuming no rainfall for the next 24 hours were found in the range of 0.23 m – 0.35 m, 0.36 m – 0.56 m and 0.49 m – 0.76 m. Both cases show good correlation ($R^2 > 0.92$) established for 12hr lead time forecast. Meanwhile, R^2 were found in the range of 0.86 – 0.88 (18hr lead time forecast) and 0.73 – 0.84 (24hr lead time forecast) for both cases.

Verification (using 1998 flood data) results indicated that, 0.51 m, 0.12 m, 0.16 m, 0.2 m, 0.23 m were found as the simulation error, 6hr, 12hr, 18hr and 24hr lead time forecast errors, respectively. Good correlation with R^2 greater than 0.840, 0.983, 0.981, 0.975 and 0.967 were obtained with respect to the simulation, 6hr, 12hr, 18hr and 24hr forecasts. The flood hydrograph analysis (approximately 3 weeks of analysis period) showed that all errors increased slightly as compared to the overall simulation and forecast (approximately 2 months). Catchment water balance of the Modified Tank Model has been assessed with satisfactory results.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

UJIAN DAN PENILAIAN KE ATAS MODEL RAMALAN BANJIR (MODEL TANGKI UBAHSUAI) BAGI KAWASAN TADAHAN SUNGAI KELANTAN

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Satu model ramalan banjir, bernama Model Tangki Ubahsuai telah diuji untuk kawasan tadahan Sungai Kelantan (12056 km^2). Data-data paras air sungai dan hujan bagi tempoh 6 jam telah dikumpulkan dari Bank Data, DID dan dijadikan data input kepada Model Tangki Ubahsuai. Pembetulan regresi telah digunakan untuk memperbaiki pwnyelakuan paras air sungai di Jambatan Guillemard (stesen ramalan). Kaedah statistik dan fungsi objektif telah digunakan untuk menilai keupayaan tangki model untuk meramal dan penyelakuan..

Data-data musim banjir sepanjang 4 tahun (1990, 1991, 1992 dan 1994) telah digunakan dalam penyelakuan manakala data bagi tahun 1998 pula telah digunakan untuk mengesahkan prestasi Model Tangki Ubahsuai. Satu set pekali tangki yang sesuai dengan tatarajah tangki yang dipilih bagi tadahan Sungai Kelantan telah diperolehi dengan kaedah cuba ralat. Paras air sungai di Jambatan Guillemard berjaya selaku dengan purata kesilapan sebanyak 0.59 m (7.8%) dan $R^2 > 0.81$. Model Tangki Ubahsuai didapati mampu menyelaku dan meramal 'rising limb' hidrograf serta air larian puncak bagi ramalan 6 jam, 12 jam dan 24 jam. Korelasi yang baik ($R^2 > 0.97$) dan ralat sebanyak

0.16 m telah diperolehi bagi ramalan 6 jam. Sementara itu, purata kesilapan sebanyak 0.2 m (2.6%), 0.24 m (3.1%) dan 0.28 m (3.8%) dan R^2 dalam lingkungan 0.96 dan 0.97 telah diperolehi bagi ramalan 12 jam, 18 jam dan 24 jam masing-masing.

Ramalan paras air sungai yang tepat amat bergantung kepada ketepatan ramalan hujan masa depan. Dalam kajian ini, dua andaian kuantiti hujan telah dibuat untuk menilai keupayaan ramalan Model Tangki Ubahsuai dalam operasi ramalan sebenar. Andaian pertama (anggapkan kuantiti hujan yang sama berlaku bagi 24 jam seterusnya) telah memberikan kesilapan dalam lingkungan 0.26 m – 0.36 m, 0.36 m – 0.49 m dan 0.45 m – 0.59 m bagi ramalan 12 jam, 18 jam dan 24 jam masing-masing manakala ralat bagi andaian kedua (Anggapkan tiada hujan berlaku) didapati jatuh dalam lingkungan 0.23 m – 0.35 m, 0.36 m – 0.56 m dan 0.49 m – 0.76 m. Kedua-dua andaian memberikan korelasi yang baik iaitu $R^2 > 0.92$ untuk ramalan 12 jam. R^2 didapati antara 0.86 – 0.88 bagi ramalan 18 jam dan antara 0.73 – 0.84 bagi ramalan 24 jam untuk kedua-dua kes.

Keputusan pengesahan (menggunakan data banjir 1998) Model Tangki Ubahsuai menunjukkan kesilapan sebanyak 0.51 m, 0.12 m, 0.16m, 0.2 m dan 0.23 m masing-masing diperolehi bagi penyerupaan, ramalan 6 jam, 12 jam, 18 jam dan 24 jam. Korelasi yang tinggi iaitu R^2 lebih daripada 0.840, 0.983, 0.981, 0.975 dan 0.967 telah dicapai bagi penyeruaan, ramalan 6 jam, 12 jam, 18 jam dan 24 jam masing-masing. Analisis hidrograf banjir (≈ 3 minggu jangka masa analisis) telah menunjukan kesemua ralat telah bertambah sedikit jika dibandingkan dengan penyerupaan dan ramalan keseluruhan (≈ 2 bulan). Pengimbangan air tadahan bagi Model Tangki Ubahsuai juga telah ditaksirkan dan keputusan yang memuaskan diperolehi.

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I certify that an Examination Committee met on 13th July 2001 to conduct the final examination of Ho Kwee Hong on her Master of Science thesis entitled "Calibration and Evaluation of a Flood Forecasting Model (Modified Tank Model) for Kelantan River Basin" 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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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

HO KWEE HONG

Date: 5 September 2001

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a	tank coefficient
f	infiltration capacity
h	depth of tank in mm
i	intensity
n	number of data
q	runoff in mm
t	time
B	catchment basin
C	tank coefficient
E	evaporation
H	height of tank outlet in mm
I	infiltration
K	side tank outlet coefficient
L	main stream length
P	precipitation
Q	runoff in mm
R	rainfall
S	weighted mean stream slope
U	urbanisation factor
V	channel velocity in m/s
X	height of tank
C_t	topography coefficient

L_c	main stream length from catchment centroid in miles
P_e	excess precipitation
Q_g	ground water flow
Q_o	overland flow
Q_t	throughflow
R^2	correlation coefficient
t_c	time of concentration
hr	hour
Lg	lag time
Mb	exponential coefficient
Q_o (s)	saturation overland flow
R (t)	precipitation at a given time
AR	autoregressive coefficient
DB	Dabong
EV	evaparation
JG	Guillemard Bridge
KK	Kuala Krai
KT	Kampung Tualang
SQ	simulated discharge
Adj	adjusted
ANN	Artificial Neural Network
HLA	hybrid learning algorithm
MAE	mean absolute factor
DID	Department of Irrigation and Drainage

FFC	Flood Forecast Centre
LPM	Linear Perturbation Model
LVL	simulated flood level
MMS	Malaysian Meteorological Services
NWS	National Weather Service
QIN	inflow
RES	residue
RMS	root mean square error
RFC	River Forecast Centre
SLM	Simple Linear Model
TCM	Thames Conceptual Model
Q_B	runoff of basin
AE_B	area evaporation of basin
IHCM	Institute of Hydrology Conceptual Model
OLVL	observed flood level
QOUT	outflow
SIMQ	simulated flood level
SMAR	soil moisture accounting and routing
TARM	Genetic Threshold Auto-Regressive Model
TS_B	tank storage of basin
TS_C	tank storage of channel
USGS	United State Geological Survey
BFLOW	baseflow
FCSTQ	forecast flood level

INFIL	infiltration
SSARR	Streamflow Synthesis and Reservoir Regulation
TR-20	Technical Release No. 20
INFIL_B	basin infiltration
Arain_B	areal rainfall of basin
$OLVL4_{min}$	minimum observed flood level
$OLVL4_{mean}$	mean observed flood level

CHAPTER I

INTRODUCTION

Tropical countries like Malaysia has an equatorial climate with constantly high temperatures (mean monthly temperature about 27°C) and high relative humidity all year round. Peninsular Malaysia has an area of 131 795 km^2 that lies approximately between latitudes 1°N and 7°N and longitudes 100°E and 105°E. The average annual rainfall is estimated at 2420 mm (600 mm daily rainfall in extreme cases) (Keizrul and Chong, 2001). Peninsular Malaysia is abetted by the North-East Monsoon that prevailing between November and February and causes heavy rainfall deposited along east coast of Peninsular including Kelantan State, one of the most significant affected area. South-West Monsoon prevails from April to September but bring less rainfall as it loses much of its moisture over the mountains of Sumatra.

According to Azmi (1992), flooding is a significant natural hazard during monsoons that affects 2.7 millions people within the 29000 km^2 of flood prone area in Malaysia. Figure 1.1 shows the flood area of Peninsular Malaysia. Therefore, various studies and strategies, both structural (engineering) and non-structural (non-engineering) measures have been proposed in tackling the flood problems. Flood forecasting and warning system is one of the non-structural approach which is more practical and least expensive to minimise flood losses as compared to the structural measures.

Flood forecasting technique used in Malaysia since 1960's was originally called Stage-Correlation Method. Throughout the years, it has been progressively upgraded and

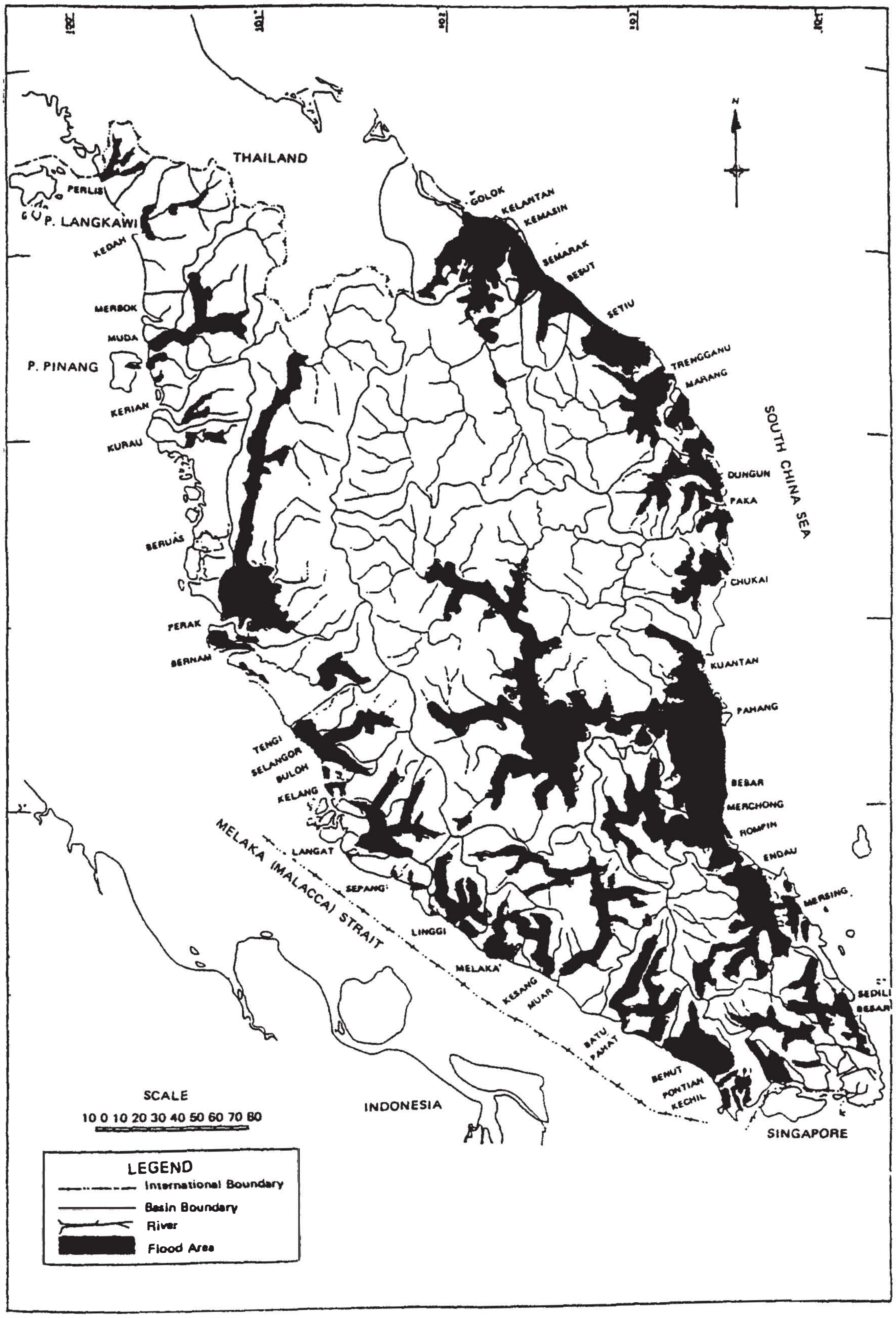

Figure 1.1: Flood prone area of Peninsular Malaysia. (Sources: Paridah, 1995)

improved. Presently, real-time rainfall and river stage data obtained through telemetric systems as well as empirical and mathematical forecasting computer models to carry out the flood forecasts. The forecast on impending floods will enable residents in flood prone areas to be forewarned and take necessary actions to protect their properties and livestock, and thus reduced serious flood damages.

Definitions of flood

The definitions of floods given by different hydrologists and researchers are as follow

"A relatively high flow as measured by either gage height or discharge rate whenever the stream channel in an average section is overtaxed, causing overflow to the usual channel boundaries, the stream is then said to have flood stage."

(Jarvis, 1949)

"Stage at which the stream channel becomes filled and above which is overflows its banks" (Wisler and Brater, 1957)

"The result of runoff from rainfall and/or melting snow in quantities too great to be confined in the low water channels of streams." (Linsley, 1964)