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MANAGEMENT OF UNCERTAINTY FLOOD INTO A LARGE WEIR SYSTEM IN THAILAND

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ABSTRACT

The Upper Yom River Basin in Phrae province, Thailand with the catchment area of 5,500 km^2 was chosen as a flood study upstream of an existing weir using the Integrated Flood Analysis System: IFAS. It was calibrated to the large flood in 2011, verified in 2003 and 2006 using the global satellite rainfall and ground-based observation rainfall. The results of synthesis inflow hydrographs from IFAS showed that it was satisfied on model performance compared to the observation data during flood period in 2011 with annual flood frequencies of 59 years and fitted to the Nash and Sutcliffe Efficiency: NSE of 0.07, R^2 of 0.58, RMSE of 253.8 m^3/s, and the observed peak flood discharge of 1,133.7 m^3/s, respectively. The result will be benefit to flood management of the weir system in the light of climate change impacts.

Keywords: Rainfall-Runoff model; Flood Frequency; IFAS; Weir Operation.

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1. INTRODUCTION

Most of the river basin in developing country is generally a lack of hydrological data collection from the field and difficulty in flood estimation which can be considered as Prediction in Ungauged Basin: PUB [1]. Accurate estimates of stream runoff and other hydrologic quantities are needed for numerous purposes of water resources planning and management. The way of obtaining such estimates by modeling methods such as the Rational Method and the index-flood method have been widely used, which can be found such as the Hydrologic Modeling System: HEC-HMS [2]. Some physical based model such as the Soil and Water Assessment Tool: SWAT [3], is a river basin scale model developed to quantify the impact of land management practices on water with the main components i.e. weather, surface runoff, return flow, percolation, evapotranspiration, losses, etc. In addition, a well-known hydro-dynamic open source program, the River Analysis System: HEC-RAS [4], is designed to perform one and two-dimensional hydraulic calculations for a full network of natural and constructed channels with graphical user interface on several hydraulic design features and water surface profiles with different managing rules of gate or structures. Recently, the distributed rainfall-runoff hydrological open source model, the Integrated Flood Analysis System [5], [6], has been widely developed which can be applied to the very large watershed, i.e. the Chao Phraya Basin, Indus River Basin, SEA countries [7], Pakistan [8], Taiwan [9], and Japan [10]. The proper selection of grid sizing in the IFAS should be carefully undertaken otherwise the longer computation time occurs [11].

The management of weir irrigation systems without any upstream dam as a head-water source, usually shows poor performance such as in the Upper Yom River Basin, Thailand [12]. The fluctuated water levels at weir due to uncertainty upstream inflow leads to difficulty gate operation for those irrigation systems as well. Since the Yom is the fourth largest tributary river of the Chao Phraya River Basin with no any large dam yet, therefore, flood problem is commonly seen and apart leads to large flood occur in the Chao Phraya Basin as well [13], [14]. Thus, this study aims to efficient weir and gate operation by using the IFAS as to simulate upstream flood as the inflow into an existing weir with different flood events.

2. MATERIALS AND METHODS

The assessment on flood inflow into the large weir system using IFAS was applied to predict the flood from a known amount of rainfall in the Upper Yom River Basin upstream of an existing weir: Mae Yom Weir in Song district. Phrae province, Thailand. The IFAS was calibrated to the largest flood event in 2011, and verified in 2003 and 2006 with ground based observation rainfalls in the basin.

The Yom River originates from the Doi Khun Yuam ridge in Phayao province having length of 735 km and flows via Phrae, Sukhothai, Phitsanulok, Phichit provinces to the confluence with the Nan River at Chumsaeng district in Nakhon Sawan province in the south direction, respectively with total drainage area of 23,618 km^2. The Upper Yom Basin above an existing weir was focused to research the influence of uncertainty inflow to the weir (Fig.1).

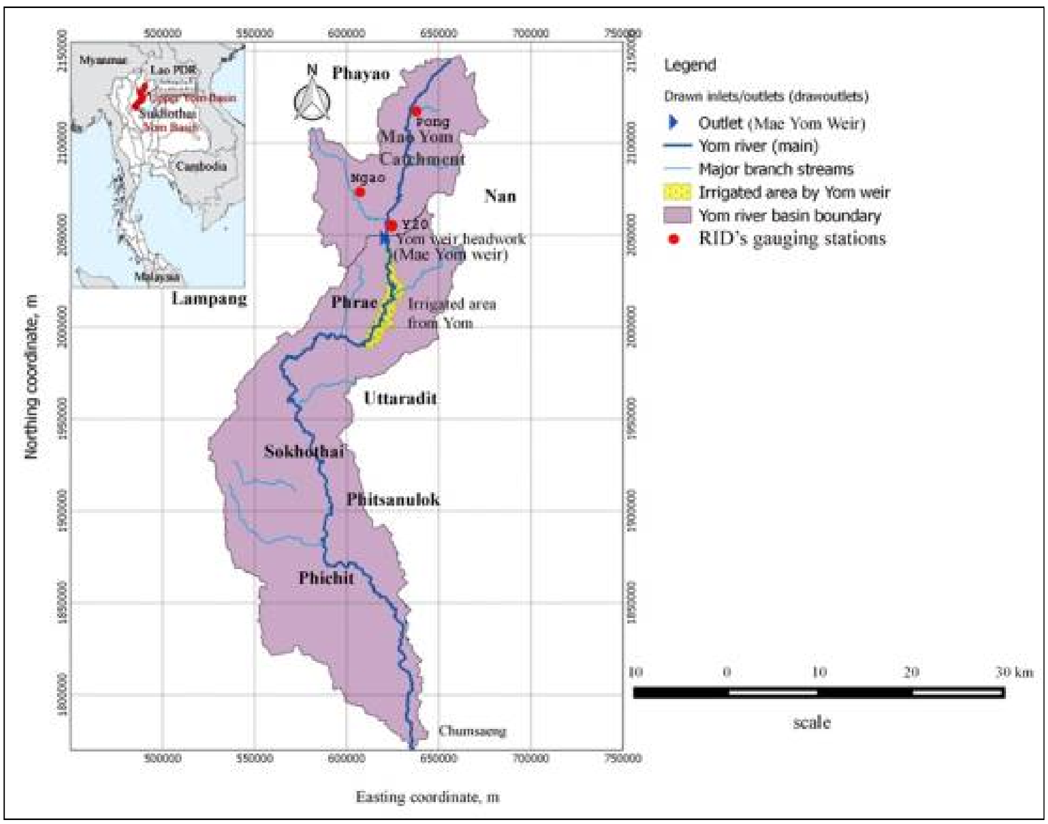

Fig.1. Map of Yom Basin and study area in the Upper part of an existing weir

An ogee type concrete weir with a height of 7.50 m and 350 m long, as a head-work for the Mae Yom Irrigation Project was built by the Royal Irrigation Department: RID since 1947. It's catchment area is approx. 5,500 km^2. There are several rain-gauge stations in the basin, but 3 of them, Y20 (15.3 km upstream of the weir), Ngao, and Pong were chosen as for the rainfall data input to IFAS using Thiessen polygon. An average annual rainfall is approx. to 1,171.7 mm and annual runoff of 1,423 million m^3 (MCM) measured at Y20's observation station of the Northern Centre for Irrigated Hydrological Office, RID.

The Gumbel distribution or the Extreme Value type-I: EV-I was applied as flood frequency analysis correspond to the maximum flood flow events based on annual rainfall that occur according to the occurrence years [15]. In this area the ground-based rainfall and streamflow data recorded by RID in the period from 1973 to 2015 were used to analyze flood frequency.

IFAS, a distributed hydrological model, which was developed by the International Centre for water Hazard and Risk Management: ICHARM [5], [6]. The general feature and grid cells divided of water balance as the tank model 3-layers with 4-tanks as IFAS conceptual diagram [16] are shown (Fig.2 and Fig.3).

In this study, the model was set up using 2-layers, 3-tanks with surface, groundwater and river course tank. The input was rainfall and the outputs were surface or streamflow, rapid intermediate outflow, and infiltration as the tank surface. The rapid intermediate and infiltration outflows are approx. proportional to the water stored in the soil.

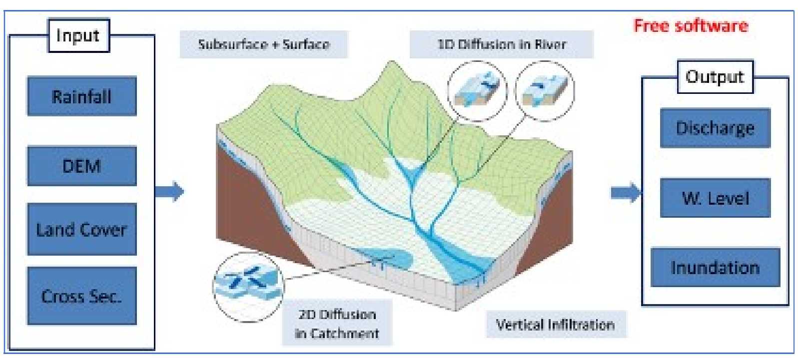

Fig.2. The general feature of the IFAS [16]

The surface flow and the rapid intermediate outflows will flow into the river course tank while infiltration flow flows to the ground water tank. The percolation inflow through the upstream surface, the ground water tank: lower tank calculates two outlets flows: unconfined and confined groundwater based on water height of the model with respect to the height from which unconfined aquifer outflow occurs.

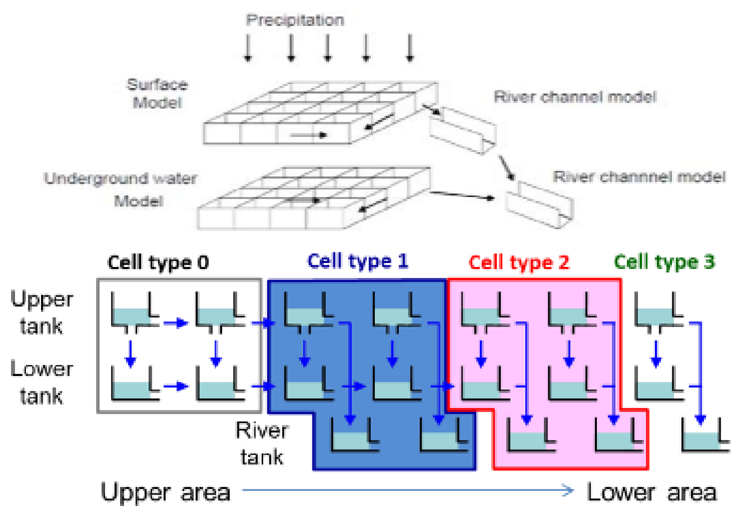

Fig.3. The schematic diagram and grid cells of the tank models using in IFAS [16]

For the river course tank, the flow of river channel was assumed to be governed by Manning's formula as inflow through the upstream surface and ground water tanks. The basin and river network setup in the upstream od an existing weir was applied with grid cell size of 1.0 x 1.0 km^2 (Fig.4) The grid resolution was selected to provide realistic delineation of the sub basins and river network. IFAS provides direct access to global data sets for DEM, land use, and satellite based rainfall. The ground-based daily rainfall at Ngao, Pong, and Y20 from the Thai Meteorological Department: TMD and RID in 2003, 2006, and 2011 were spatially interpolated to grid cell using Thiessen Polygons. The digital elevation data from GTOPO30, land use data from the Global Land Cover Characterization: GLCC with 30 arc-second resolutions were auto retrieved from the IFAS. The major parameters to be used for the calibration are infiltration capacity: f_0, max. water height: S_{f2}, height of the rapid intermediate flow: S_{f1}, height of the ground infiltration occurs: S_{f0}, and roughness coefficient: N (Fig.5).

Nash-Sutcliffe Efficiency: NSE [18], correlation coefficient: R^2, and Root Mean Square Error: RMSE were selected to assess the performance of IFAS with the model calibration data in 2011, and verification in 2003 and 2006 with ground-based rainfall.

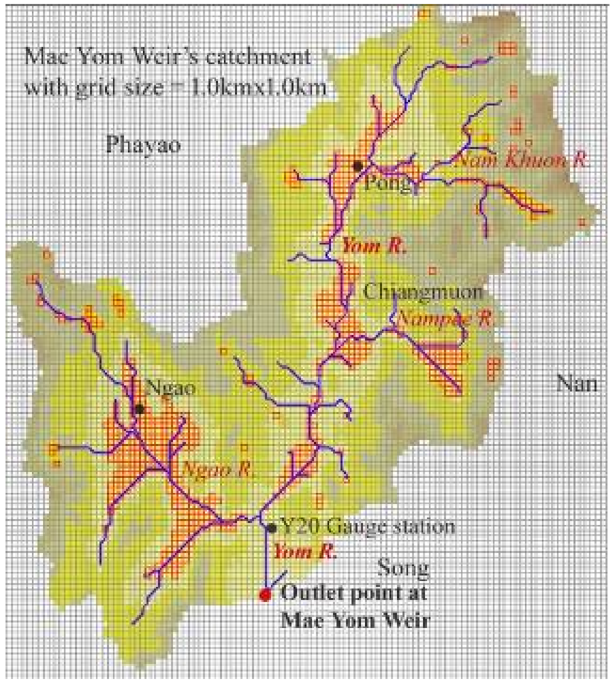

Fig.4. Topography and stream networks using GTOPO30 upstream of an exist weir

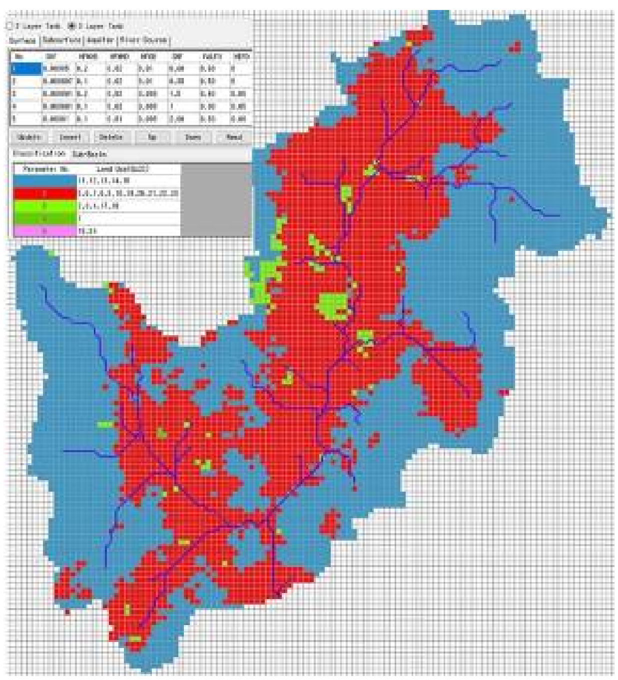

Fig.5. Parameters of surface tank in study area

3. RESULTS AND DISCUSSION

The calibrated parameters in tank's characteristics were applid in the model (Table 1).

Table 1. Calibrated parameters at upstream weir used in the model

Parameter	Symbol	Notation	Unit	Applied
Final infiltration capacity	f_0	SKF	cm/s	$1x10^{-6}$ - $5x10^{-4}$
Max. water height	S_{f2}	HFMXD	m	0.001-01
H. where rapid Intermed. flow	S_{f1}	HFMND	m	0.0005-0.01
H. where ground infiltra. occurs	S_{f0}	HFOD	m	0.0005-0.005
Roughness coef.	N	SNF	$m^{-1/3}/s$	0.035-0.1
Rapid intermed. flow reg. coef.	α_n	FALFX	-	0.5-0.9
Initial water h.	-	HIFD	m	0-0.05

The daily river discharge computed by IFAS using ground-based rainfall in 2011, with the annual runoff of 3,335 MCM and the return period of 59 years fitted to the observed discharge data at Y20 as the model calibration using NSE of 0.07, R^2 of 0.58, RMSE of 253.8 m^3/s, and the peak flood discharge of 1,133.7 m^3/s, respectively (Fig.6).

The ground-based observed rainfall data during flood period in 2003 and 2006 produced the annual runoff of 1,483 and 1,828 MCM with the return period of 2.3 and 5.9 years, used as the model validation as an example of the result in year 2006 shown (Fig.7). The simulated inflows from IFAS agreed well with the observations in 2006. The results in both years 2003 and 2006 fitted to the NSE of 0.37 and 0.64, R^2 of 0.59 and 0.17, RMSE of 176.9 and 235.3 m^3/s, and peak flood discharge of 994.0 and 861.5 m^3/s, respectively. Therefore, IFAS is capable of simulating daily inflows from upstream to an existing weir.

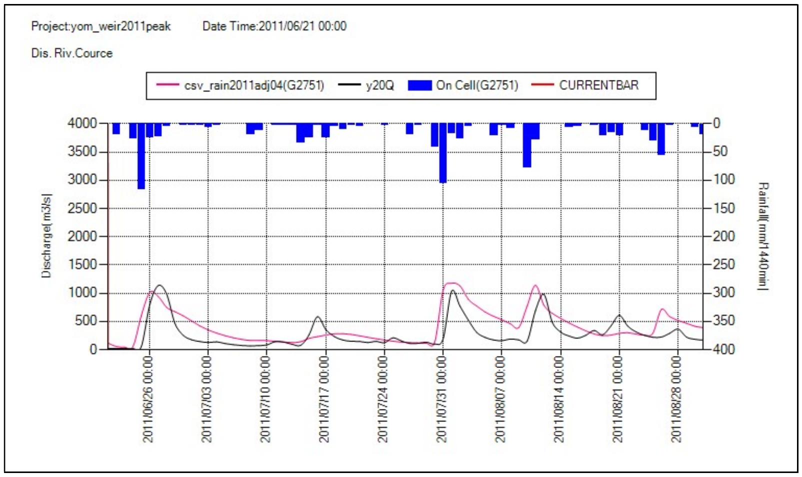

Fig.6. Comparison of calibration result of runoff and observed data at Y20 in 2011

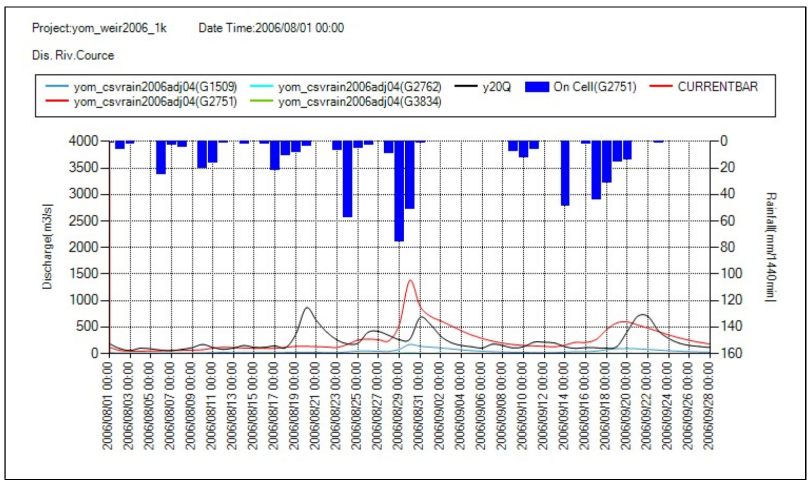

Fig.7. Comparison of validaated result and observed data at Y20 and other in 2006 grids

4. CONCLUSION

The distributed hydrological model using IFAS was capable enough to simulate daily flood from upstream of an existing weir from the Upper Yom River Basin. It is a high enough of the correlation coefficient and is also capable of capturing peak flows. Results from this study illustrate the average conditions in the management of the gate operation rule of both gates standing at the weir crest and offtake structures on both sides of the Yom in future. The IFAS can assist to increase the weir operation efficiency during flood season in the light of climate change impacts. Further consideration of extreme events and inter-annual variability could help provide a more completed view on the weir operation to optimally mitigate floods and droughts in the long term.

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6. REFERENCES

[1] Blöschl G. Predictions in ungauged basins – where do we stand? Proceedings of the International Association of Hydrological Sciences, Copernicus Publications, 2016, 373: 57-60 (See also URL http://www.proc-iahs.net/373/57/2016/)

[2] US Army Corps of Engineers: USACE. Hydrological Modeling System HEC-HMS. Washington, DC, 2017 (See also URL http://www.hec.usace.army.mil/)

[3] Arnold JG, and Fohrer N. SWAT2000: Current Capabilities and Research Opportunities in Applied Watershed Model. Hydrological Process, 2005, 19: 563-572 (See also URL http://dx.doi.org/10.1002/hyp.5611)

[4] US Army Corps of Engineers: USACE (2016). HEC-RAS's User Manual. Washington, DC, 2016 (See also URL http://www.hec.usace.army.mil/)

[5] Sugiura T, Fukami K, and Inomata H. Development of Integrated Flood Analysis System (IFAS) and its applications. World Environmental and Water Resources Congress, 2008, 1-10

[6] PWRI. Integrated Flood Analysis Systems: IFAS Ver. 2.0 User's Manual, 2017 (See also URL http://www.icharm.pwri.go.jp/research/ifas/)

[7] Shrestha BB, Okazumi T, Miyamoto M, Nabesaka S, Tanaka S, and Sugiura A. Fundamental Analysis for Flood Risk Management in the Selected River Basins of Southeast Asia. J. of Disaster Research, 2014, 9(5): 858-869

[8] Aziz A, and Tanaka S. Regional parameterization and applicability of Integrated Flood Analysis System (IFAS) for flood forecasting of upper-middle Indus River. Pak. J. Meteorol, 2011, 8: 21-38

[9] Kimura N, Chiang S, Wei HP, Su YF, Chu JL, Cheng C, and Lin L. Tsengwen Reservoir Watershed Hydrological Flood Simulation Under Global Climate Change Using the 20 km

Mesh Meteorological Research Institute Atmospheric General Circulation Model (MRIAGCM). Terrestrial, Atmospheric and Oceanic Sciences, 2014, 25(3): 449-461

[10] Sugiura A, Fujioka S, Nabesaka S, Tsuda M, and Iwami I. Development of a flood forecasting system on upper Indus catchment using IFAS. In Proceedings of the 6th International conference on flood management, ICFM, 2014, 1-12

[11] Fukami K, Sugiura Y, Magome J, and Kawakami T. Integrated Flood Analysis System: IFAS Ver. 2.0 User's Manual. Japan PWRI-technical note, Inc., 2014, 238-259

[12] RID. Efficient Rehabilitation Study of the Mae Yom Operation & Maintenance Project in Phrae Province. Executive Summary and Main Report (in Thai), prepared by Naresuan University, Thailand, 2017

[13] Hungspreug S, et al. Operational Flood Forecasting for Chao Phraya river Basin. Proceedings of the International Conference on The Chao Phraya Delta: Historical Development, Dynamics and Challenges of Thailand's Rice Bowl, Bangkok, 2000

[14] Japan International Cooperation Agency: JICA. The Study on Integrated Plan for Flood Mitigation in Chao Phraya River Basin. Summary and Main Report, Royal Irrigation Department, Kingdom of Thailand, 1999

[15] Chow VT, Maidment DR, and Mays LW. Applied Hydrology, McGraw-Hill, 1988

[16] Sayama, T, et al. Rainfall-Runoff-Inundation Analysis of Pakistan Flood 2010 at the Kabul River Basin, Hydrological Sci. J., 2012, 57(2): 298-312

[17] Shiraishi SY, Fukami K, and Inomata H. The proposal of correction method using the movement of rainfall area on satellite-based rainfall information by analysis in the Yoshino River Basin. Annual Journal of Hydraulic Engineering, JSCE, 2009, 53: 385-390

[18] Nash JE, Sutcliffe JV. River flow forecasting through conceptual models, Part I - A discussion of principles, Journal of Hydrology, 1970, 10: 282–290

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