Annual Journal of Hydraulic Engineering, JSCE, VOL.47, 2003, February

FLOOD FLOW PATERN AND DISTRIBUTION OF INFILTRATION OVER LARGE FLOODPLAIN AND NATURAL GROUNDWATER RECHARGE AREA

Sombat CHUENCHOOKLIN[1], Tsutomu ICHIKAWA[2] and Sa-nguan PATAMATAMKUL[3]

[1]Ph.D Candidate Water Resources Eng., Graduate School, Khon Kaen University (Khon Kaen, 40002, Thailand)
[2]Member of JSCE, Dr. of Eng., Professor, Dept. of Civil Engineering, Kyushu Tokai University (9-1-1, Toroku, Kumamoto, Japan)
[3]Ph.D, Assoc. Prof., Dept. of Civil Engineering, Faculty of Engineering, Khon Kaen University (Khon Kaen, 40002, Thailand)

A study of flood flow pattern in floodplain of a large river in the natural groundwater recharge area during flood period from 2001 to 2002 is presented. The floodplain of the Yom River in Phichit Province, Thailand, was carried out during flood period 2001 and 2002. Some phenomenon in hydrological processes especially runoff, infiltration and flood flow patterns has been studied. Field experiments for infiltration testing by using ring-infiltrometers were carried out corresponding recorded time and water depth. Laboratory testing was done for studying some properties of soil samples especially for infiltration speed through soil column, which were collected from the field. Due to the site of study is located in ungauged catchments with lack of for hydrological data but some had been generated using available data from other catchments nearby the site. The simple water balance model was applied to this study. Mapping represents flood flow patterns and distribution of infiltration rates. The results showed the potential for further study of flood reduction via deep percolation from floodplain.

Keywords: Floodplain, infiltration, water budget, and natural groundwater recharge

1. INTRODUCTION

In generally for floodplain catchments of the large river, the phenomenon of surface and subsurface flow was very close relationship that should not be separately considered in each situation, particularly for floodplain that locates in natural groundwater recharge basin. Most of floodplain area is suitable for rice cultivation because of soil fertility by flood, which carried alluvium soil from the river. Some physical phenomenon in hydrological system in floodplain such as flood flow pattern, runoff characteristics, infiltration and other relevancies should be clearly investigated by using such as water budget or water balance method. The results of study can be applied for further efficient floodplain management with the real-time flood forecasting systems.

2. STUDY AREA

The Yom River is one of four largest tributaries of the Great Chao Phraya River's Basin in Thailand that watershed is 23616 sq. km. However, this research just selected some 170 sq. km in large floodplain of the Yom River in Phichit Province. Usually the occurrence of flood that overflows from the Yom River starts from the mid to late of wet season that lies from upstream at Sukhothai via Phitsanulok, Phichit, and joins to the Nan River at Nakhonsawan Province. This research has been conducted to investigate flood flow pattern in floodplain of the Yom River and its distribution of infiltration over the natural groundwater recharge basin in Phopratabchang Distrcit, in Phichit Province, as shown in **Fig. 1** as the aim of a part to study a potential for flood mitigation by groundwater recharging using the water balance model.

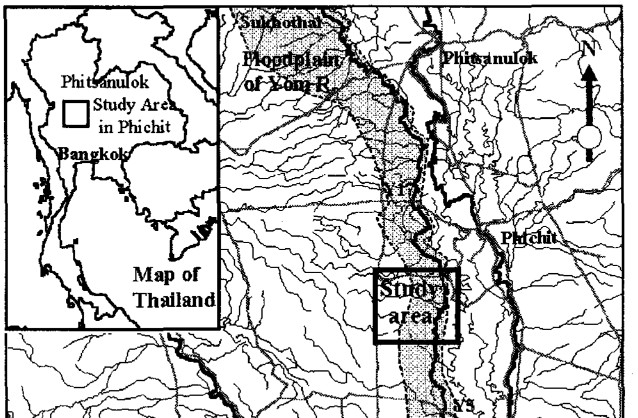

Fig. 1 Map of the Yom River's floodplain and study area in Phopratabchang District, Phichit Province, Thailand.

The study area locates in 6 sub-districts, these are Noensawang, Wangjik, Dongsualuang, Phairob, Phopratabchang and Phaithapho in Phopratabchang District, as shown in **Fig. 1**. The climate in Phichit is typical tropical-monsoon whose rainfall in 2001 was 1127.5 mm, rainy day was 99 days and September was the most intense rainfall with 243 mm as recorded at Noenkwang School (P3) by KTU (Kyushu Tokai University) collaborated research [1].

Topography of the study area is flat slope. The Yom River lays on the eastern part of study area with total length of 21 km from upstream at Wangjik (1) via Phopratabchang (2), Phaitapho (3), and downstream end at Lamnang (4) w hich the direction of flow is north to south. Its floodplain is very wide lowland area with 79 sq. km, as shown in **Fig. 2**. Mono-crop growing in floodplain area is just only high-yield-variety rice, which normally grows during early wet season, this must be harvested prior flood attack. The characteristics of geomorphology in this area are conformed by shallow clay or silt layer which is on the topsoil. The lower layers are unconfined aquifer by sand or gravel layer which are alternated by clay layer which results moderate yield of groundwater from this aquifer, so that a lot of shallow and deep wells have been drilled by farmers. Because they want to supply water for their plants during the drought period, or for the second crop due to lack of surface water from the sources in dry season.

There are 3-local streams which are tributaries of the Yom River that flow into the upstream, middle, and downstream of study area: Phairob (I1), Nongkla (I2), and Dongsualuang (I3), respectively. The study area has been bounded by 3 main roads: No.117, No.1276, No.1070, and RID's Flood Protection Dike (DK2), that lay on the west, the north, the south, and the east of the study site, respectively, as shown in **Table 1** and **Fig. 2**.

3-D view of the study area in floodplain of the Yom River, Phichit Provinc

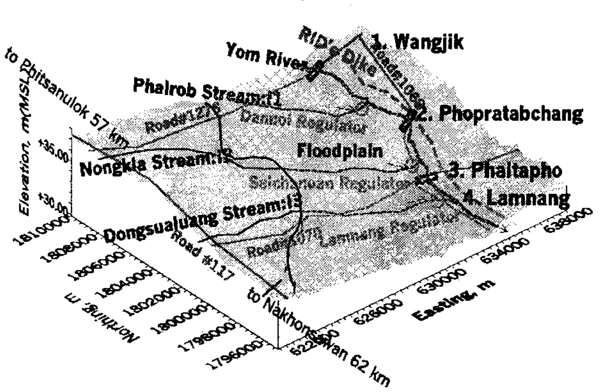

Fig. 2 Map shown details of study area: streams, and contour lines

There are 22 existing observation-wells in this study area which were installed by KTU in order to analyze groundwater flow and time series recording for most physical groundwater phenomena.

Table 1 Configuration of 3-local streams in the study area

Local streams name	Catchment Area, km^2	Length, km	Average slope	Tail Regulator name
Phairob	48	24.8	0.000172	Dannoi
Nongkla	36	12.5	0.000358	Saichanuanyai
Dongsualuang	160	59.4	0.000194	Lamnang

3. METHODOLGY AND THEORETICAL CONSIDERATION

(1) Configuration of study site

Site selection locates in natural groundwater recharge basin and large floodplain of the Yom River. Contour-lines were constructed by available data collection from RID, Highway Department (HWD), aerial map from Royal Thai Survey Department (RTSD), existing surveying, and flood mapping[5].

Simulation of water surface profile along the Yom River to study area via 11-existing cross-sectional profiles was carried out by using the standard-step method and verified by daily river flow data from RID's gauging stations at Y17 and Y5 which locate at 34.680 km to upstream and 37.200 km to downstream measured at Phopratabchang Bridge, respectively, as shown in **Fig. 2** and **Fig. 3**. The river analysis system model[4] has been applied by typically using energy equation or Bernoulli and flow equation which based on Manning formula for particular river reaches[2), 4)]. Area of flood extent over floodplain can be estimated from the relationship of water depth and volume that based on existing map, cross sectional profiles and contour lines, as shown in **Fig. 4**.

(2) Conceptual model

Model figure has been designed by the assumption of using of simple water balance method as shown in **Fig. 3**.

Water budget as a continuity equation for the study area, as Eq. (1)

$$\{Q_{simup}(t)+Q_{in1}(t)+Q_{in2}(t)+Q_{in3}(t)+Q_{o}(t)-Q_{simout}(t)\}+P(t)\cdot A-ET(t)\cdot A-I(t)\cdot A=\Delta V(t,H) \qquad (1)$$

where Q_{simup}, Q_{simout} are simulated discharge at upstream and downstream of the site, Q_{in1}, Q_{in2}, Q_{in3}, those are lateral inflows discharge on the right bank of the Yom River from Phairob, Nongkla, Dongsualuang streams, respectively. However, the area on the left bank of the Yom River which is controlled by flood protection dike (DK2) along the Yom River and amount of drainage discharge from irrigated area into the Yom River will not be considered in this model.

Q_o is inflow discharge from overflow from the Yom River across riverbank and levee or roads into the study area.

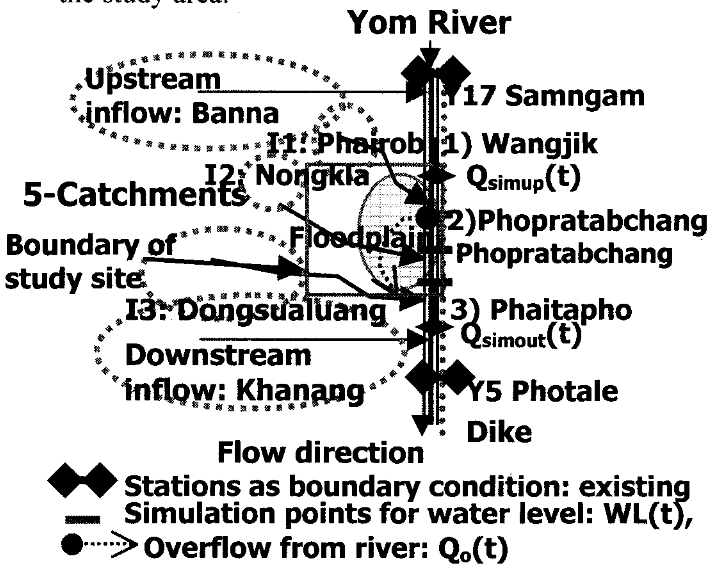

Fig. 3 Model of water balance for floodplain of the Yom River in Phichit Province

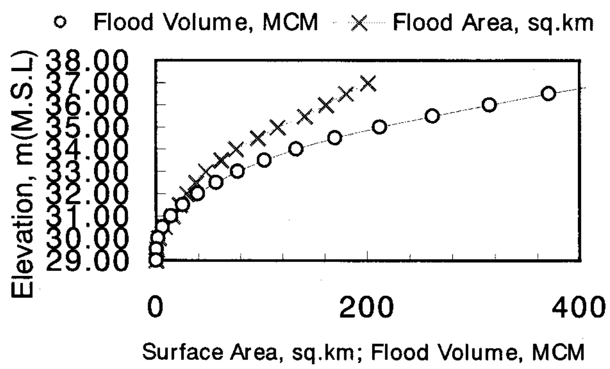

Fig. 4 Relationship flood level, area-volume in study area.

P is the precipitation, ET is the evapotranspiration, t equals to 1-day for time increment. ΔV, the increment of flood volume corresponds to flood depth for each time step. The fluctuation of water table can be considered as some contributed capillary rise to surface flow from vadose zone, which will directly affect the rate of infiltration. However, no accounting from this action during flood problem was considered in this model. The effects of groundwater contributions from seepage are just considered from the Yom River not included the Nan River and irrigation canals which are nearby the study area on the left side.

Lateral inflow discharges of the Yom River at upstream and downstream outside of study area (**Fig. 3**) were simulated as Q_{simup} and Q_{simout} using rational formula (Q=CiA) with mean annual runoff coefficient (C) over the total catchment area (A) with 1953 sq. km and existing rainfall intensity (i). Those 3-local streams in existing study area: I1, I2, and I3, unfortunately, there is no any gauging station for data recording yet. Simulation of those inflows was estimated using existing coefficient of runoff from the rational method combined to the synthetic hydrograph based on SCS-method[2] with actual daily rainfall. Flood amount which came from overtop bank (Q_o) will be considered as inflow discharges to floodplain and result to flooded area increasing was calculated based on broad crested-weir equation overtop bank or roads from existing profiles and data.

Daily rainfall (P) was measured at the site by using automatic rainfall recorder and data logger based on of 5-minutes interval[1]. Other weather datas were collected from this research and MD (Meteorological Department).

Unfortunately, it lacks of some data especially about land utilization for crop cultivation and cropping pattern, so the combined Penman-Monteith method (FAO, 1977), or pan evaporation method[3] is selected to calculate crop water requirement. It depends on available existing weather data which is nearby the site. In this study, ET from class-A pan evaporation method was chosen.

Losses by infiltration rate (I) into the soil were measured from field experiment at many points that located in the study site by using double ring-infiltrometers with varied water depths versus passing time. The relationship between the applied water depth versus recording time, and water depth versus infiltration rate at the initial period were fitted by graphical method. The depth of water infiltrated to the soil could be found by using the following equations, as Eq.(2)

$$D = at^{b}, \quad I(t) = a \cdot bt^{b-1} \qquad (2)$$

where D is an accumulated water absorption depth in soil in mm, I(t) is infiltration rate varying with time (t) and head of water (H), a and b are constants from the slope in logarithm scale. However, when the soil is nearly saturated after infiltration, which nearly constant rate occurs continuously until at the beginning of harvest season or during drain out of water from the field.

Then, flood depth (H) or inundated water at next time step can be determined as the following equation, as Eq.(3)

$$H_{t2} = H_{t1} + \Delta H(t) \qquad (3)$$

Flood extent area (A) can be estimated using graphical result of contour lines versus flood volume over measured surface area from existing aerial map (H versus A&V), which uses to draw flood pattern.

Finally the change of flooded volume (ΔV) over floodplain can be computed by using Eq.(1).

(3) Field experiments

The measurement of field infiltration testing by using double ring infiltrometers were tested during dry season 2001/2002 for 14 points and during wet season 2002 for 10 points, as explanation in **(2)**, and **4**. There were 3-plots locate in floodplain paddy field for testing daily water consuming infiltration losses during period of rice growing in wet season 2002.

Field observation of water depth and discharge measurement along local streamflows at road structures and regulated structures using current meter were occasionally carried out during wet season 2002 in order to fit relationship of rainfall and streamflow which used to verify the model.

(4) Laboratory experiments

Soil samples were collected from the field by undisturbed soil column and brought to laboratory in order to find soil characteristics and hydraulic conductivities for unsaturated and saturated condition with constant and varied applied head.

Both of field and lab testing results were used to estimate infiltration losses correspond to actual ponded water depth over floodplain. It meant that flood could be reduced by these phenomena.

Table 2 Results of field infiltration in dry season 2001/2002

Type	Site no.	D=a.t^b		I=a.b.t^{b-1}		R^2
		A	b	a.b	b-1	
N; Non flood zone	1	11.029	0.0642	0.7081	-0.9358	0.8993
	2	29.029	0.0949	2.7549	-0.9051	0.5273
	8	13.412	0.0593	0.7953	-0.9407	0.8144
	9	12.055	0.0430	0.5184	-0.9570	0.9181
	12	22.993	0.0564	1.2968	-0.9436	0.9375
	13	19.400	0.0535	1.0379	-0.9465	0.6066
	14	16.899	0.0580	0.9801	-0.9420	0.5835
F; Flood zone	3	10.766	0.0754	0.8118	-0.9246	0.9691
	4	10.751	0.0592	0.6365	-0.9408	0.8537
	5	21.021	0.1357	2.8525	-0.8643	0.9609
	6	7.9475	0.1127	0.8957	-0.8873	0.8703
	7	16.165	0.0715	1.1558	-0.9285	0.8351
	10	12.653	0.0690	0.8731	-0.9310	0.8528
	11	14.830	0.0670	0.9936	-0.9330	0.8355
Mean N		*17.831*	*0.0613*	*1.0935*	*-0.9387*	***0.8247***
Mean F		*13.448*	*0.0844*	*1.1344*	*-0.9156*	*0.8103*
Infiltration: N		*1.676*	*Mean infiltration*		*1.660 mm/d*	
Infiltration: F		*1.644*				

4. RESULTS

Field testing result for infiltration can be categorized into flooded and non-flooded zones in dry season 2001/2002 which 7-sites located in flooded zone (no.3, 4, 5, 6, 7, 10, and 11) and other 7-sites located in non-flooded zone (no.1, 2, 8, 9, 12, 13, and 14), as shown in **Fig. 5**. The results in 2001/2002 were summarized, as shown in **Table 2, Fig. 6** to **Fig. 9**.

Field-testing results of infiltration and in wet season 2002 with 10 sites in flooded zone (1w, 2w, 3d, 4w, 5d, 6d, 7w, 8d, 9w, and 10w) were given, as shown in **Table 3 and Fig. 10** to **Fig. 12**.

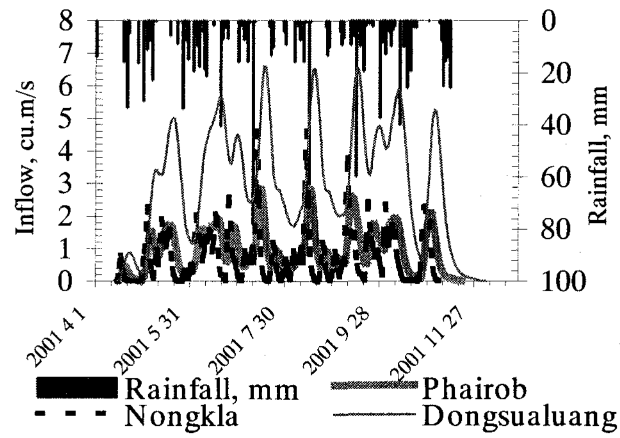

Fig. 5 Simulation result of daily local inflow discharges to study area using SCS's method.

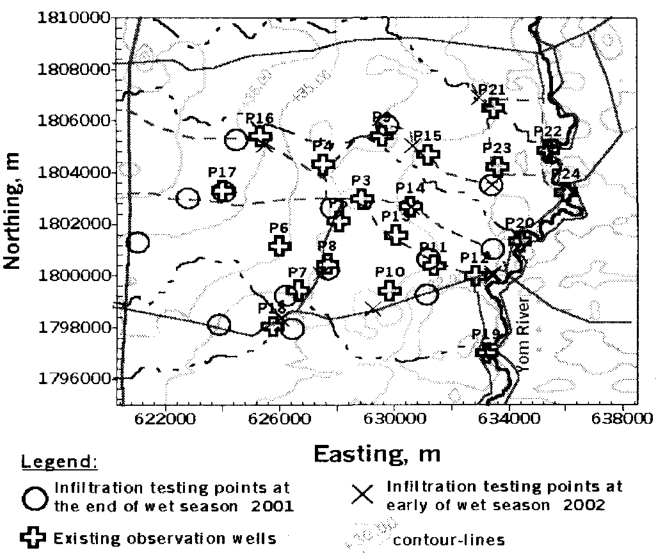

Fig. 6 Points of field infiltration testing in year 2001and 2002

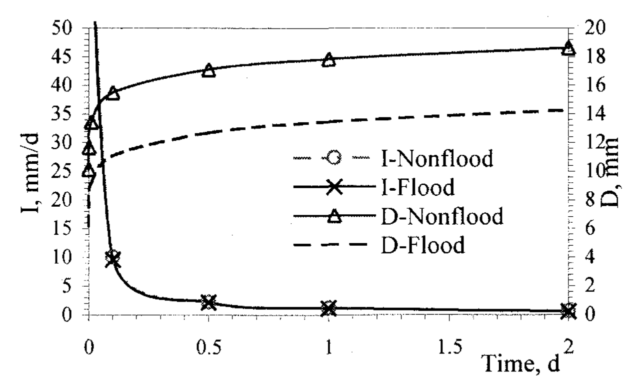

Fig. 7 Results of field infiltration in dry season 2001/2002

Infiltration speed of soil samples from 3-sites (no. 1, 2, 3) were tested in laboratory with the mean value for dry season 2001/2002 of 1.748x10^{-6}, and

4.038×10^{-7}, while for wet season 2002 with 1.856×10^{-6}, and 1.783×10^{-7} m/s for unsaturated, and saturated condition, respectively. The results show that field infiltration testing was less than the result from laboratory because topsoil layer in the paddy field which usually is clay or silt, has been compacted by farm-tractor and its environment. But for soil sample was normally less disturbed condition than field leading to looser soil.

Table 3 Results of field infiltration in wet season 2002

Type	Site no.	$D=a.t^b$		$I=a.b.t^{b-1}$		R^2
		a	b	a.b	b-1	
Wet	1w	7.707	0.5056	3.897	-0.4944	0.9743
Wet	2w	6.659	0.5529	3.682	-0.4471	0.9930
Dry	3d	74.660	0.9376	70.000	-0.0624	0.8442
Wet	4w	14.050	0.4775	6.708	-0.5225	0.9500
Dry	5d	79.370	0.3225	25.596	-0.6775	0.9592
Dry	6d	213.33	0.5655	120.632	-0.4345	0.9746
Wet	7w	2.226	0.5103	1.136	-0.4897	0.9598
Dry	8d	249.36	0.5140	128.180	-0.4860	0.9645
Wet	9w	13.160	0.3617	4.759	-0.6384	0.8403
Wet	10w	26.978	0.4846	13.074	-0.5154	0.9985
Mean Wet		11.797	0.4821	5.687	-0.5179	0.9526
Mean Dry		154.10	0.5849	90.179	-0.4151	0.9356
Infiltration: W		4.636				
Infiltration: D		*76.145*	Note: W=wet, D=dry conditions			

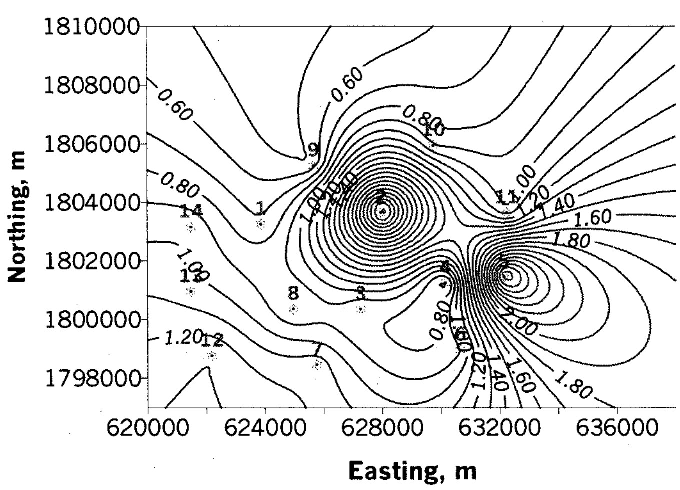

Fig. 8 Distribution of field infiltration dry season 2001/2002

The results of occasion daily observed flood depth and extent area could plot into flood mapping and flood pattern. The field observed of flood depth which infiltrated leaded to gradually increase groundwater level.

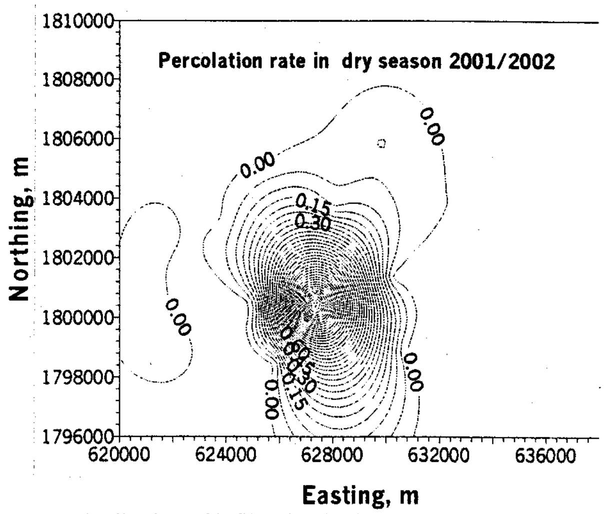

Fig. 9 Distribution of infiltration in dry season 2001/2002.

Daily rainfall in 2001 of 11.4 mm/d resulted side-flow volume of 742 MCM and coefficient of runoff of 0.3371. The local inflows of 92 MCM or the mean discharge of 4.58 cu.m/s were simulated, as shown in **Fig. 5**. Simulated daily river flow and water level in the Yom River into study site were shown in **Fig. 13**. An example for computing flood extent on 2001 by HEC-RAS River Analysis System[4] was presented, as shown in **Fig. 14**. Result of flood extent and flood flow pattern was simulated, as shown in **Fig. 15**. However, the relationship of flood volume versus water level in study site was temporary stored until the top of road height. Then the flow would overtop road flow out to downstream and furthermore the storage would be reduced if flood recession limb is occurred.

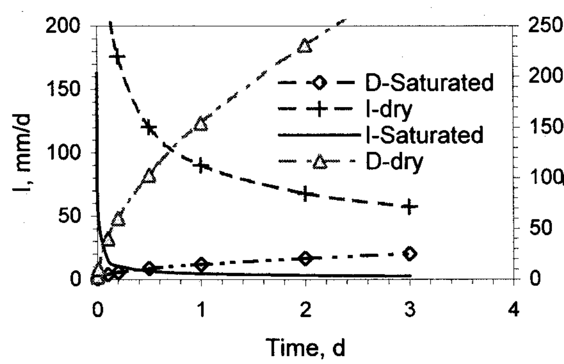

Fig. 10 Results of field infiltration rates in wet season 2002.

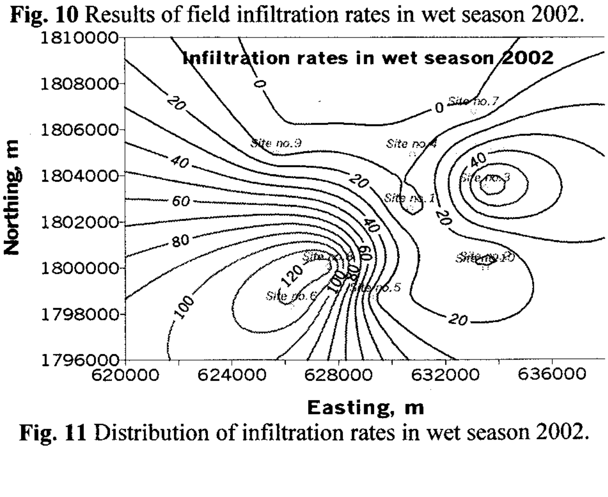

Fig. 11 Distribution of infiltration rates in wet season 2002.

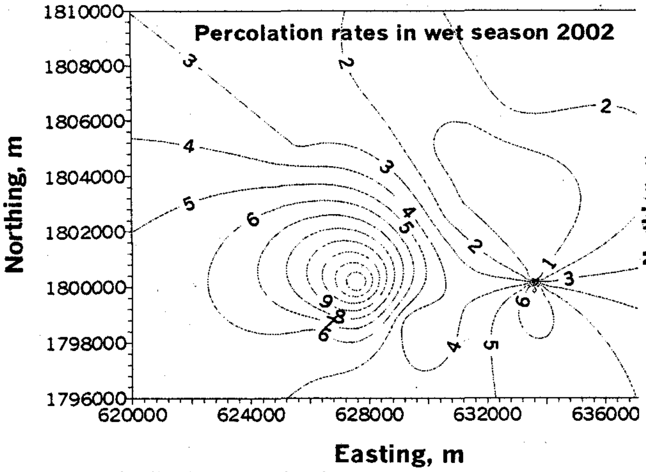

Fig. 12 Distribution of infiltration rates in wet season 2002.

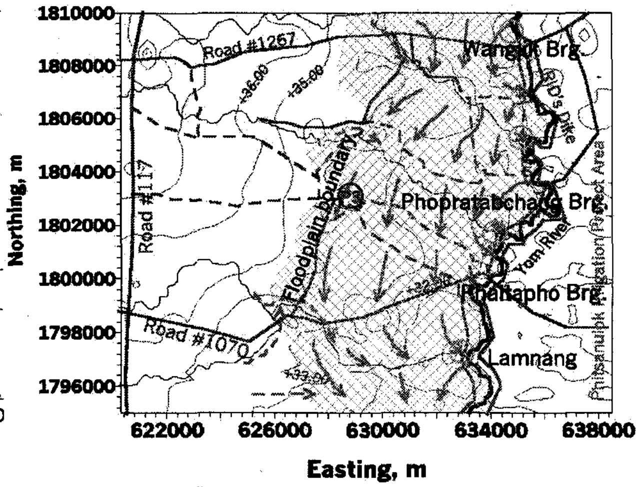

Fig. 15 Flood flow pattern from the Yom River to floodplain in the study area, Phopratabchang District, Phichit Province.

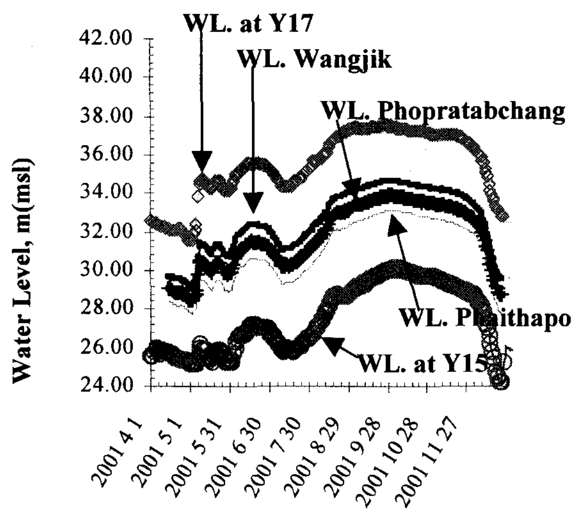

Fig. 13 Daily water level along the Yom River from Y17 to Y5 via study area at Wangjik, Phopratabchang and Phaitapho.

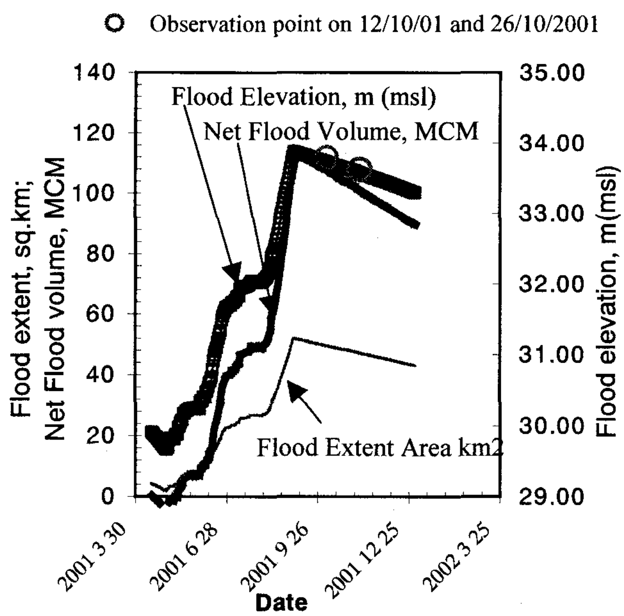

Fig. 14 Simulated daily flood extent over study area in 2001.

5. CONCLUSION

From this study, flood extent area can be estimated correspondingly by inflow from branch streams and overtop bank flow from the main river. The major cause of flood extent comes from overflow from the main river. Infiltration processes over floodplain could a little bit reduce flood depth through topsoil layer and go downward via lower soil layers with hydraulic conductivity.

The results lead to increase in groundwater level, which are quite good results for further study of the potential for flood reduction through shallow aquifer by infiltration from floodplain.

ACKNOWLEDGEMENT: The authors would like to thank Asst. Prof. Pattaraporn Mekpruksawong; Planning and Project Office, the Royal Irrigation Department (RID) for her supervision and contribution with great support for some budget, and instruments for this research.

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(Received September 30, 2002)