# Control and mitigation of floods along transbasin diversion channel of Mekong tributaries and Nan river, Thailand

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## Abstract

Flood flow along the Upper Nan river including its upstream rivers namely Yot and Yao in northern Thailand is simulated covering a flow distance of about 100-km from A. Tha Wang Pha to A.Wiang Sa . The models used are the MIKE 11 flood routing model, the NAM rainfall-runoff watershed model and the HEC-5 reservoir routing model. The models are calibrated using the observed daily rainfall and flood flow data during the flood periods in 1993 and 1995 and verified using the data in 1988. The results of the calibration and verification are found to be satisfactory. Considering natural inflows and transbasin diversion flow, the models are applied to predict the flood conditions along the Upper Nan river due to transbasin diversion inflow from the adjacent Kok and Ing river basins. The change in the flood levels due to the transbasin diversion inflow and the given design rainfall conditions of 25 and 100 year return periods are determined. The flood control schemes consisting of a flood control reservoir in the Yao river and diking along the Upper Nan river are recommended

Keywords: flood control reservoir, mathematical model, river diking, transbasin tiversion

## INTRODUCTION

The Chao Phraya river basin, Thailand has a total drainage area of 178,000 $km^2$ and an irrigation area of 1.5 million ha. Two major tributaries namely Ping and Nan rivers merge to become the Chao Phraya river at Nakhon Sawan . There are two main storage dams namely Bhumibol in the Ping river and Sirikit in the Nan river. The release from the two reservoirs is diverted by the Chao Phraya irrigation diversion dam to the downstream irrigated areas on both sides of the river. In the last few decades there has been a dramatic increase in downstream water demand due to increase in dry season irrigation and in other water use sectors. On the other hand the inflows to the reservoirs are reduced due to increase in upstream urbanization and upland crop irrigation. As a result downstream water shortage occurs frequently in the past decade.

To solve the water shortage problem, it was proposed to construct a transbasin diversion scheme to divert water from the adjacent Kok and Ing rivers to the Nan river upstream due to the Sirikit reservoir (Figure 1). The amount of the water diversion from the Kok and Ing rivers to the Nan river is restricted by minimum flow requirement of the Kok and Ing rivers (Tingsanchali and Boonyasirikul, 1996; Poomthaisong, 1997). There are two types of possible structural alternatives for flood control, namely the Yao upstream flood control reservoir that will reduce downstream flood peaks and river diking to protect overbank flows. The flood control reservoir will play the role of storing the diverted water from the Kok and Ing rivers and in controlling release to downstream at the certain desired discharge at which the overbank flow will not occur. The natural floods in the Yot and Yao rivers occur for a short duration of about 1 to 1.5 days, thus the reservoir capacity should be able to store the diverted water volume during the period of downstream flooding.

The main objectives of this study are: 1) to determine the effect of the Yao flood control reservoir, 2) to determine the effect of diking along the river and 3) to suggest additional flood control work required to convey the reservoir release safely without significant flood damages in the Yao river and Nan river upstream of the Sirikit reservoir.

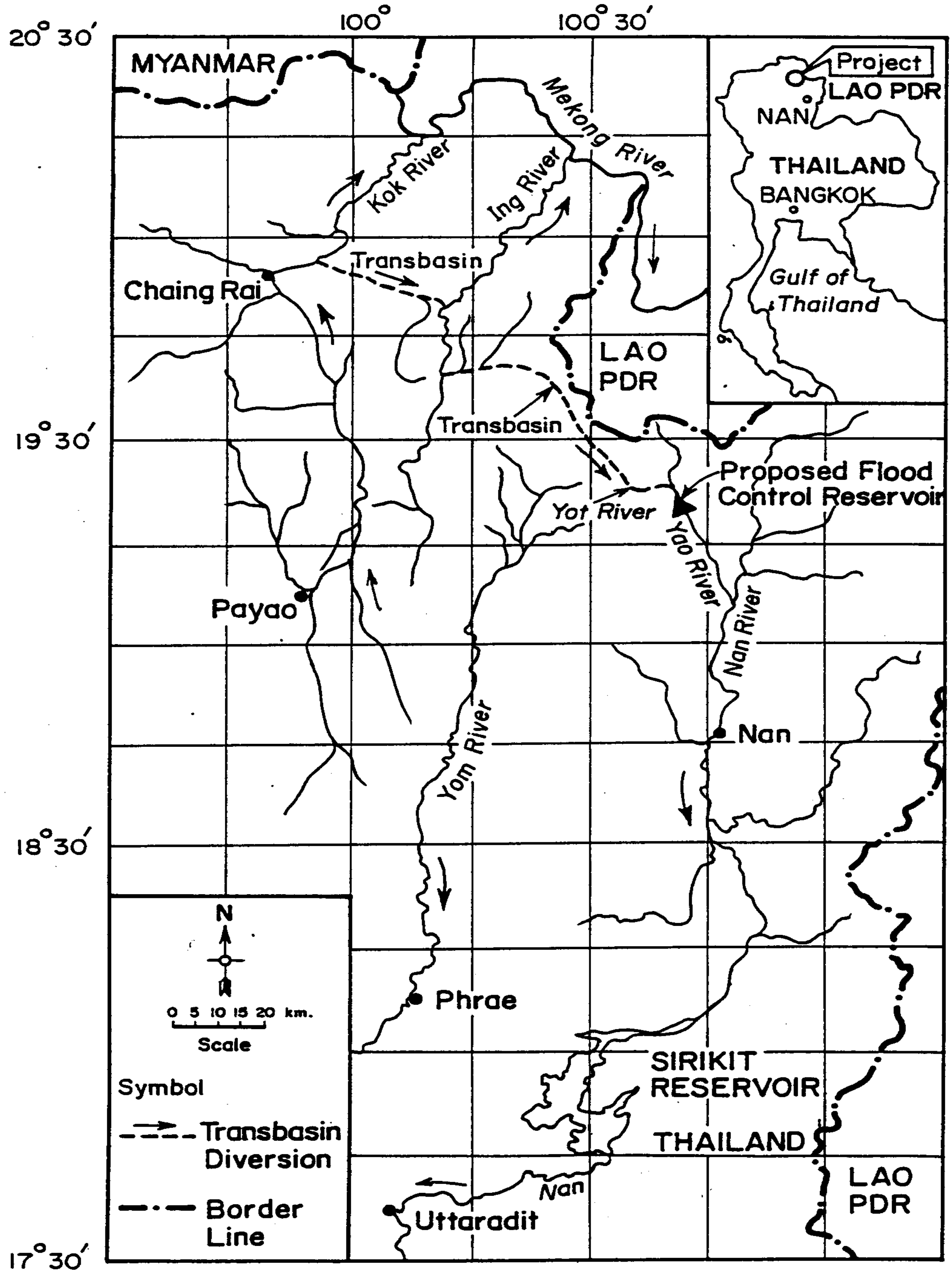

Figure 1 Proposed Kok-Ing-Yot transbasin diversion scheme, Thailand

## MATHEMATICAL MODELS

### Rainfall-runoff model (NAM model)

NAM is an abbreviation of the Danish "Nedbor-Afstromings Model", meaning precipitation runoff model. This model was developed by Nielsen and Hansen (1982) at the Institute of Hydrodynamics and Hydraulics Engineering, Technical University of Denmark. The model consists of a set of linked mathematical statements describing in a specified quantitative form the behavior of land phase of hydrological cycle. The NAM model is so called deterministic, conceptual, lumped type of model with moderate input data requirement. NAM simulates the rainfall-runoff process in rural catchments. It operates by continuously accounting for the moisture content in four different and mutually interrelated storage which represent physical elements of the catchment. The input data of the model are precipitation, potential

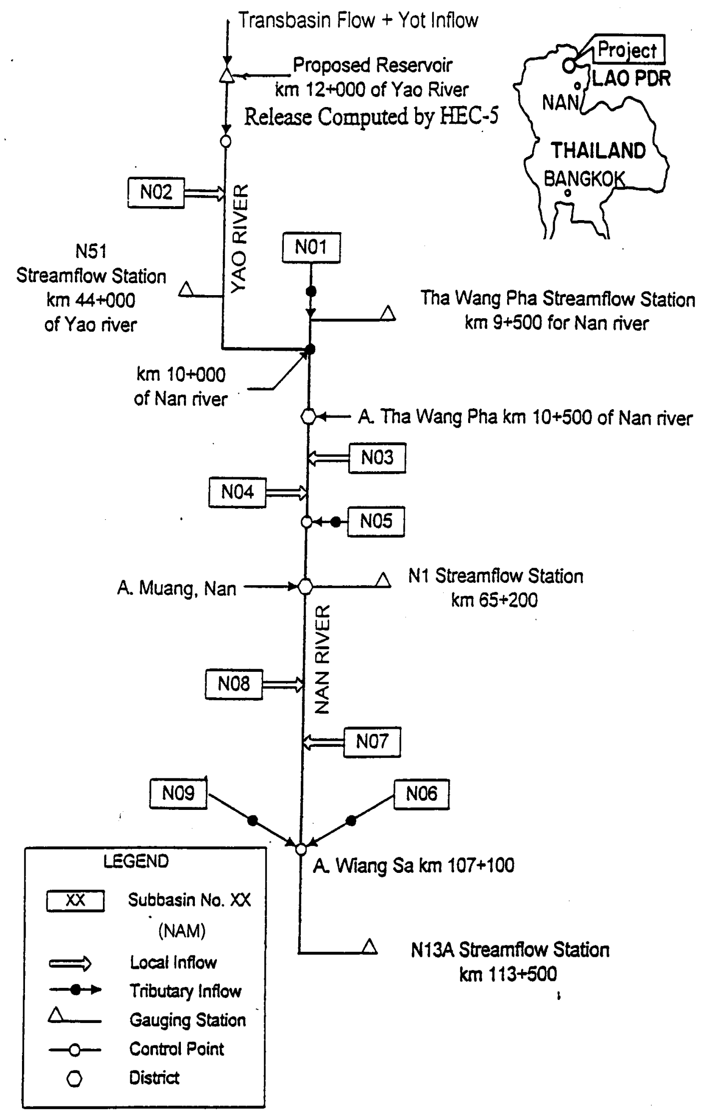


Figure 2 Model configuration for MIKE-11 and NAM model for Yao and Nan rivers

evapotranspiration and temperature (for the snow routine). On this basis, it produced, as its main results, the mean daily values of streamflow as well as information about other element of the land phase of the hydrological cycle, such as the temporal variation of the soil moisture content and the groundwater recharge.

**HEC-5 model for simulation of flood control and conservation systems (HEC-5)**
The model was developed by the Hydrologic Engineering Center (Eichert, 1975; HEC 1982) to assist in planning studies for evaluating proposed reservoirs in a system and to assist in sizing the flood control and conservation storage requirements. The program is useful in selecting the proper reservoir releases throughout the system during flood emergencies in order to minimize flooding as much as possible and yet empty the system as quickly as possible while maintaining a balance of flood control storage among the reservoirs.

**MIKE 11 – Hydrodynamic module**
The model is an implicit, finite difference model for one dimensional unsteady flow computation and can be applied for looped networks and quasi two-dimensional flow simulation on flood plains (DHI, 1992). MIKE 11 is capable of using kinematic, diffusive or fully dynamic, vertically integrated mass and momentum equations (the "Saint Venant" equations). The governing equations are the continuity and momentum equations as follows:

$$\frac{\partial Q}{\partial x}+\frac{\partial A}{\partial t}=q \tag{1}$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\alpha\frac{Q^2}{A}\right)+gA\frac{\partial h}{\partial x}+\frac{gQ|Q|}{C^2R}=0 \tag{2}$$

where Q = discharge, A = cross-sectional area, q = lateral inflow, x = distance, t = time, $\alpha$ = momentum distribution coefficient, R = hydraulic radius, g = gravitational acceleration, h = depth, C = Chezy C and R = hydraulic radius. The solution of the equations of continuity and momentum is based on an implicit finite difference scheme (DHI,1992).

## METHODOLOGY
The methodology can be described as follows:

1) Rainfall frequency analysis to determine the magnitude of 100 years design rainfall and to develop the 100 years design rainfall hyetograph for the local inflow to the Yao flood control reservoir and to the Yot, Yao and Nan rivers. The NAM model can be used to calculate local flow based on the design rainfall. The collected data are the daily rainfall, daily water level, daily discharge, stage –discharge rating curve, monthly pan evaporation from the stations inside the study area and the topographical maps of the study area.

2) Simulation of reservoir operation by using the HEC-5 reservoir system simulation model to find the release of the flood control reservoir. Therefore, data of streamflow, reservoir characteristics, flow controls and demands, and reservoir operating criteria are collected.

3) Flood control investigation of the Upper Nan river, Yot and Yao rivers by using the MIKE 11 hydrodynamic model. Therefore, the data for model calibration are the cross sections of the Yot, Yao and Nan rivers, the daily water level/discharge data during the two or three large flood periods.

## NUMERICAL COMPUTATION
**Rainfall frequency analysis**
The stations considered are within the local subbasins contributing local runoff to the Yot, Yao and Nan rivers. Gumbel distribution is used for rainfall frequency analysis (Beard, 1976). Data required are records of annual maximum daily rainfall for the last 20 years. Rainfall of return periods of 2, 5, 10, 25, 50, 100 and 500 years are estimated from Gumbel distribution of the local subbasin stations. It is noted that the daily rainfall pattern for an average year is determined by averaging the daily rainfall hyetograph of 1975 to 1995. Using the average daily rainfall pattern

and the maximum annual rainfall based on Gumbel distribution, the daily rainfall pattern for the 25 and 100 years rainfall are developed at 12 stations in the river basin.

**NAM model calibration**

The NAM model is a lumped model, it is necessary to input the representative rainfall time series which is the mean areal rainfall over a subbasin. The mean areal rainfall is determined by the Thiessen polygon method to find weighting factors of each rainfall station The criteria for model calibration is to adjust the model parameters in order to obtain satisfactory agreement between the simulated and observed discharge hydrographs. By adjusting the parameters within realistic limits, satisfactory agreement between the observed and simulated discharge hydrographs for two flood data is obtained.

**Reservoir simulation model (HEC-5)**

The HEC-5 Model simulates the release of the proposed flood control reservoir which is located in the upstream reach of the Yot river. To avoid upstream inundation, the maximum flood storage should not exceed 21.52 mcm. The inflow to reservoir consists of the pre-specified diverted water from the Kok and Ing rivers (Tingsanchali and Boonyasirikul, 1996) and the upstream local inflow from the NAM model based on the annual rainfall of 25 year and 100 year return periods. The release from the proposed flood control reservoir is computed by the HEC-5 model based on the reservoir operational rule curves given by Tingsanchali and Boonyasirikul (1996).

**MIKE-11 hydrodynamic model**

The model was calibrated by comparing the computed and observed water levels and discharges at the available gaging stations. By these comparisons the Storage Width (SW), the Resistance Factor (Rr) as well as the Manning Number M of the cross sections along the main river can be adjusted until the best fitted hydrographs of the computed and observed water levels and discharges are obtained.

## RESULTS AND DISCUSSIONS

**Proposed flood control schemes**

There are two flood control schemes proposed in conjunction to the Kok-Ing-Nan transbasin diversion schemes: 1) Yao flood control reservoir only and 2) Yao flood control reservoir and diking along the Nan river. Figure 2 shows the schematization of the hydrodynamic model of the Yot, Yao and Nan river reaches under consideration.

**Model calibration and verification**

The basin runoff from the NAM model can be adjusted depending on the selection of the characteristics of the Nan river basin. The results obtained from the NAM model for all subcatchments show that this set of parameters can simulate the hydrographs having smaller peaks during the dry periods. Also during the wet periods the rising limbs of the simulated hydrographs matched fairly well with less phase error while amplitude error is within an acceptable limit. The release of the proposed flood control reservoir in the upstream reach of the Yot river is calculated by HEC-5 model. In the computation, the inflow to the reservoir consists of the diverted water from the Ing river plus the local flow upstream reservoir computed from the NAM model. The simulated runoff from the NAM model is used as the lateral inflow to the river for flood routing in the hydrodynamic model (MIKE 11).

The release from the proposed flood control reservoir computed by the HEC-5 model has been used as the upstream boundary condition in the hydrodynamic model for downstream flood routing. The accuracy of the simulated discharges and water levels by the hydrodynamic model directly depended on the accuracy of the measured data such as bed elevations, cross-sectional data, hydraulic boundaries and the selection of Manning roughness coefficient. The results obtained from the hydrodynamic model show fairly good matching between the simulated and observed discharges and water levels along the Nan River especially during the flood peaks.

**Determining effect of flood control measures**

To determine the effect of reservoir plus diking on the flood peak levels along the rivers, the river cross-section above the berm (main channel bank) elevation is confined only within the main channel topwidth by extending vertical walls above the main channel banks. These confined main channel cross-sections are input into the MIKE 11 hydrodynamic model to compute the flood levels and discharges along the Yao and Nan rivers. From the MIKE-11 model, the computed flood levels from the hydrodynamic model at the damage areas at A. Muang, Nan province for the 100 year return period of annual rainfall in case of with and without the proposed flood control reservoir and river diking are shown in Figure 3. The envelope of the longitudinal profiles of maximum water surfaces for the 100 year rainfall is shown in Figure 4.The computed results are compared with the computed water levels and discharges for the case of having reservoir only. It is found that the construction of the reservoir alone is not sufficient to effectively reduce the flood problems. By comparing the computed flood peak levels with the main channel bank elevation, the locations where the construction of flood dikes is required to protect flood plian inundation of Nan river can be determined. Therefore both the flood control reservoir and river diking are necessary for the flood control measures.

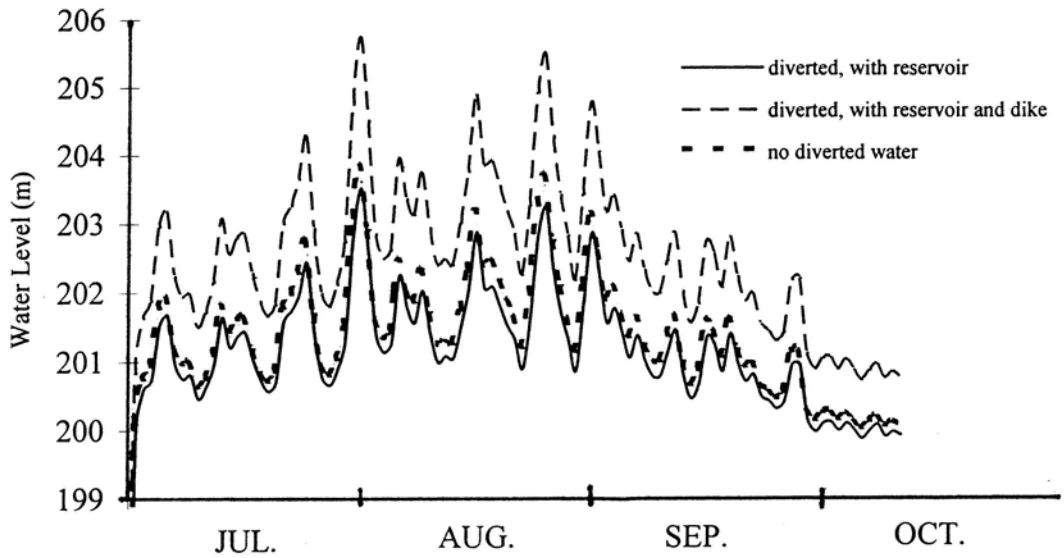


Figure 3 Computed daily water level hydrograph in Nan river at A. Muang, Nan province for 100 year flood

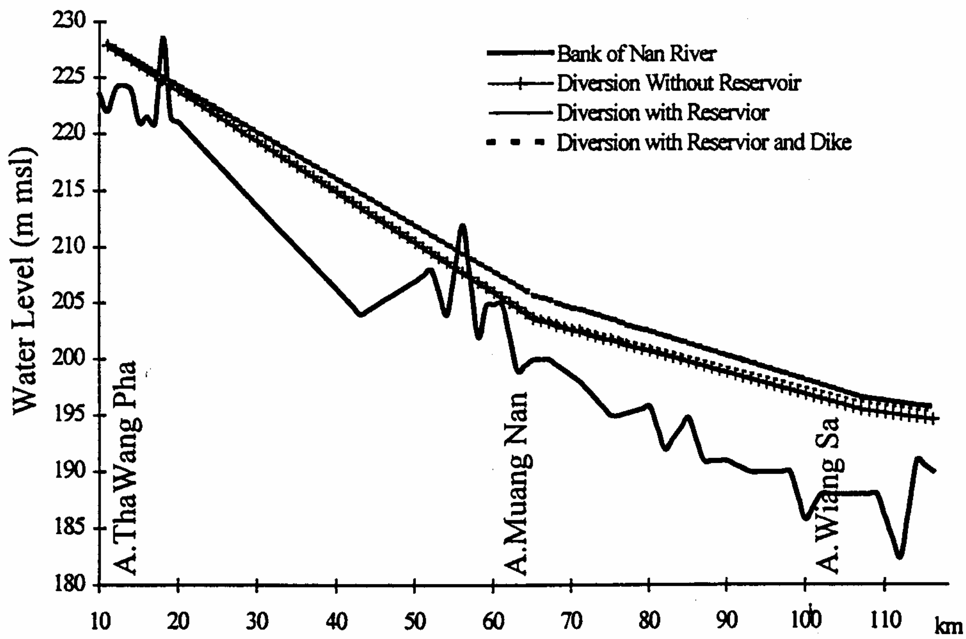


Figure 4 Computed envelope of maximum flood peak levels along Nan river for 100 year flood

**CONCLUSIONS**

Under no flood control scheme (existing condition), flooding occurs along the Nan River and the Yao River due to the 25 year and 100 year design floods. With the proposed flood control reservoir, it is found that under the 25 year and 100 year return periods of design flood, the flood peak level will be only slightly reduced compared to the case without reservoir. Therefore, the proposed flood control reservoir should be enlarged in order to store more flood water to reduce downstream flooding more effectively. However, the enlargement is restricted by the maximum water levels of the flood control reservoir due to inundation in the area upstream of the reservoir.. Due to the high flood levels, the Nan river, Yot and Yao rivers downstream of the reservoir require the construction of flood protection dikes. By the construction of the dikes and the flood control reservoir, the flood peak level is increased higher than the case with the reservoir only. However with diking, no overbank flow occurs and hence the flooding can be eliminated.

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