Financial Analysis of the Improvement of Drainage Structures on Road Network To Relief Flood in Frequently Flooded Areas in Southern Thailand[1]

Pruethipong Xinghatiraj and Attasit Sawatpanich

Introduction

Thailand has been encountering multiple damages as a result of natural disaster. Each disastrous event has increasingly become more severe particularly the flood events. The possible causes of floodare the effect of economic development and population growth, which subsequently lead to changes in land utilization, deforestation, and various transportationdevelopment projects. As such, in the presence of continuous heavy rainfall, the amount of surface runoff will increase. Particularly in road areas, if the drainage system or drainage structure is inadequate or too small, flood problems will occur repetitiously as shown in Figure 1, which negatively impact the people's live and subsequently cause damage to the road structure.

Figure 1 Inadequate Drainage Structure on Road

Regarding the design of road drainage system, the peak runoff rate is normally calculated by using equation and/or graph, which is convenient for users. The conventional methods employed by the Department of Highways are rational method, unit hydrograph, regional flood frequency analysis, and synthetic unit hydrograph. Such methods of calculating peak runoff rate have certain limitations especially in the events that catchment area is in urban region or in lowland with developeddrainage system that cannot properly collaborate with natural drainage system. These circumstances make it difficult to determine the appropriate size of catchment area, which may lead to a mistake in calculation of peak runoff rate for the design of a drainage structure.

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Thailand's Southern provinces normally suffer seasonal flash-flooding towards the end of the year. Figure 2 (bottom) shows the satellite image of flooded land near a river in Southern Thailand on January 9, 2017.This picture shows that most of the area is sediment-laden flood water. For comparison, the toppicture shows the same area on February 2, 2014, when waters were lower.

Figure 2Flood in Southern Thailand
(https://earthobservatory.nasa.gov/images/89445/floods-swamp-Southern-thailand)

	February 2, 2014
	January 9, 2017

To remedy flood problem in frequently flooded areas in Southern Thailand, a mathematical model is introduced to determine maximum flow rate through DEM data (Digital Elevation Model), satellite images, rainfall intensity, soil characteristics, etc. Comparing with the satellite images, this new maximum flow rate calculation gives more accurate result than the traditional methods. The improvement of drainage structures is then designed based on this new flow rates. Subsequently, the benefit of this concept of design is estimated based on the damages area of flood reduced. The study shows that the benefit of investment from this study can reduce damages around 27.60 million CAD per similar event.

Literature Review

Design of drainage structure employed by the Department of Highways is based on four methods: 1) Rational Method; 2) Unit Hydrograph; 3) Regional Flood Frequency Analysis; and 4) Synthetic Unit Hydrograph. The limitations of each method are concluded as follows:

Rational Method

(1) Watershed size shall not exceed 25 sq. km.
(2) Knowledge in geographical data is necessary
(3) The existing IDF curve data must be updated regularly

Unit Hydrograph

(1) Watershed size shall not exceed 1,000 sq. km.
(2) Knowledge in geographical data is necessary
(3) Hydrological data in watershed areas are required
(4) Complicated processes, solid knowledge in hydrology is necessary
(5) Complicated processes, parameters used in calculating TP and QP must be updated regularly

Regional Flood Frequency Analysis

(1) Hydrological data in watershed areas are required
(2) Complicated processes, solid knowledge in hydrology is necessary
(3) Complicated processes, formulation of relationship between QF and A, and relationship between QF and QTr are required

Synthetic Unit Hydrograph

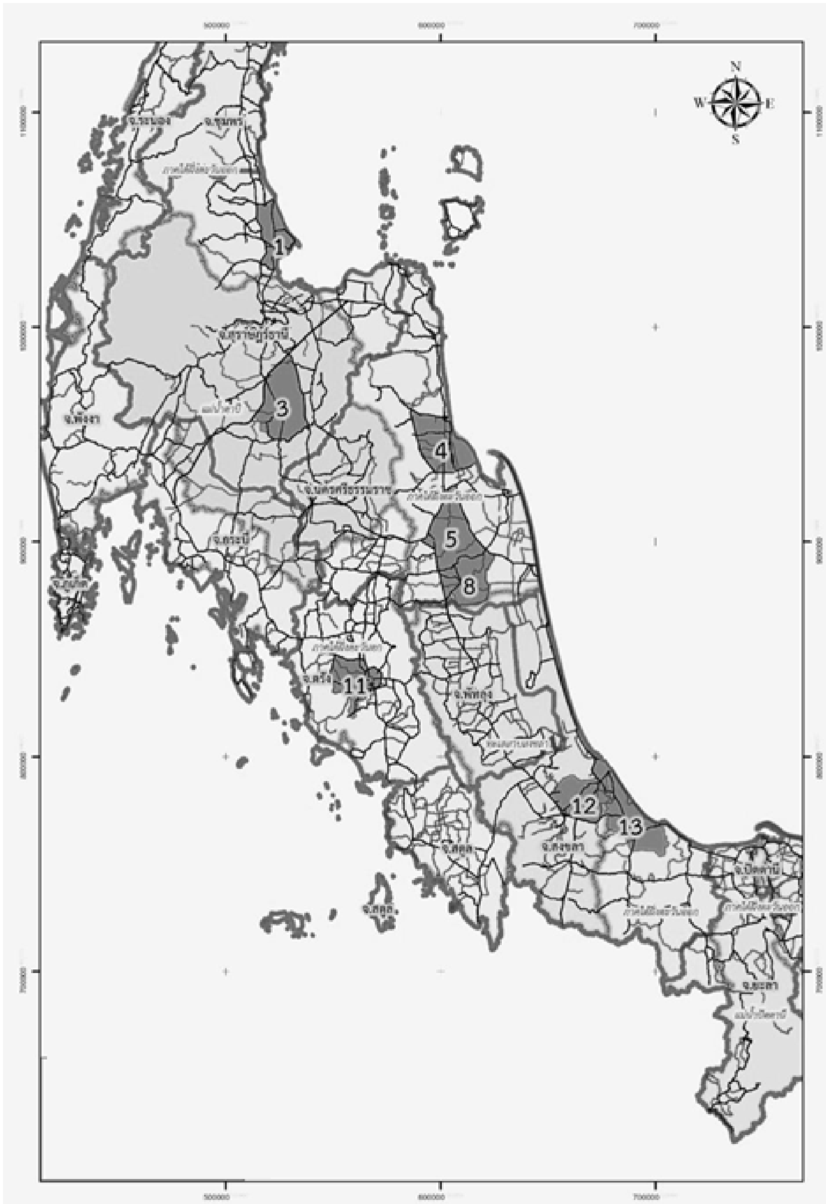
(1) Watershed sizes shall not exceed 1,000 sq. km.
(2) Knowledge in geographical data is necessary
(3) Soil characteristic data are required to estimate the rate of water transmission
(4) Rainfall areal reduction factors data are required
(5) Rainfall and runoff relationship is necessary

Area Selection

To select study areas, 15 areas of high risk of recurrent flood problems in Southern Thailand are considered. Then, among considered areas, 8 areasare selected for full analysis as shown in Figure 3.The key criteria for selecting study areas are severity of flood problem and diversity of location. Such criteria are to ensure that the selected areas are representatives of frequently flooded areas from different topographical characteristics.

These 8 area sites are investigated to collect information regarding the capacity of water drainage structures on highways. In addition, the information of DEM, rainfall intensity, soil characteristics are also collected. All these information are applied to MIKE software for determining peak runoff rate. Then, the peak runoff rate and its input data are used to model a new set of peak runoff equations. For model calibration, the peak runoff rates that yield from the developed equations are verified their accuracy by comparing their flooded area with the real flooded area from satellite images.

Figure 3 Studied Areas



Data Collection and Survey

The collected data comprise

(1) Hydrological data; rainfall data collects from 140 stations and runoff volume collects from 119 stations. The hydrological data are used for determining peak runoff rate from mathematical model software.

(2) Topographical survey data e.g. land use, digital elevation model (DEM), town plan of each province, etc. These data are used for determining peak runoff ratefrom mathematical model software.

(3) Satellite images. This study had selected a total of 8 satellite images for calibrating mathematical model.

Equation Modelling

The mathematical model employed in this study is MIKE Flood developed by Danish Hydraulics Institute in Denmark, which is one of popular software for analysing flow hydrodynamics in rivers and flooded areas. It includes both 1D and 2D hydraulic models, as well as NAM model, which are used to simulate river networks in the project areas. MIKE Flood software has a solid system of database management that can display the results of calculation in forms of chart, table, and flood map.

After the application of all collected data on MIKE flood program, all peak runoff rate and their inputs (hydrological data and topographical data) are used to formulate a new set of peak runoff rate equations. The multiple regression analysis is used in this study. The results show that type of land use is key factor dominatesflooding on frequently flooded area in Southern Thailand. The developed peak runoff rate equations are

For South East River Basin	Qpeak = 2.563 + 0.542LL +0.184HL + 6.776Wat + 0.734Res
For SongKhla Lagoon River Basin	Qpeak = 0.557Agi + 0.611Res
For Tapi River Basin	Qpeak = 0.131HL + 0.142Res
For South West River Basin	Qpeak = 0.141Agi + 0.142Res

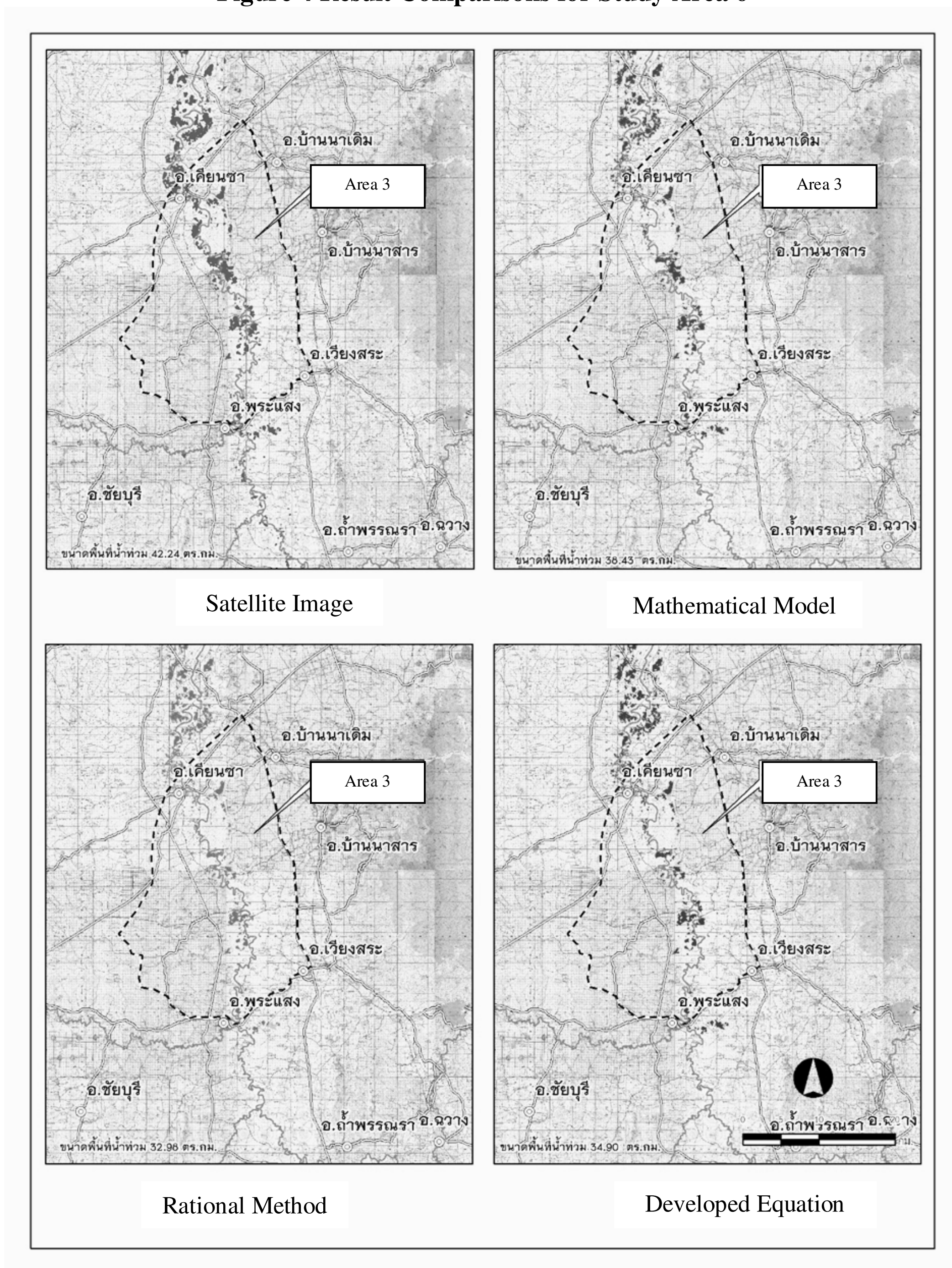
Where	Qpeak	is	Peak runoff rate (cubic meter/second)
	LL	is	Low Land area (square kilometer)
	HL	is	High Land area (square kilometer)
	Agi	is	Agriculture area (square kilometer)
	Res	is	Residential area (square kilometer)
	Wat	is	Water resource area (square kilometer)

Comparison of Equations' Effectiveness

To compare equations' effectiveness, the estimated peak runoff rates obtained from equation above are normalized by the peak runoff rate obtained from MIKE program (Mathematic Model). The result obtained is the ratio of adjusted peak runoff rate to simulated peak runoff rate. In addition, the rational method, which is the most familiar method used in design of drainage structure, is calculated and also normalized by the simulated peak runoff rate. Such ratiosare used to calculate flooded area. For purpose of comparison, it is noted that all predicted peak runoff rates from mathematic model, developed equation and rational method are determined under the sameinput conditions.

As described above, the performance of peak runoff rate from new formulated equation, rational method, and mathematical model are compared. Such comparisonsare conducted by comparing those results of flooded areas with actual flooded areas obtained from satellite images. For illustration, a result isshown in Figure 4. Comparing new formulated equation and rational method, it can observe that flooded areasforecastedby new formulated equation are more consistent with areas obtained from satellite image. Accordingly, it can be concluded thata result fromdeveloped peak runoff rate equation provides more accuratethan that from traditional method.

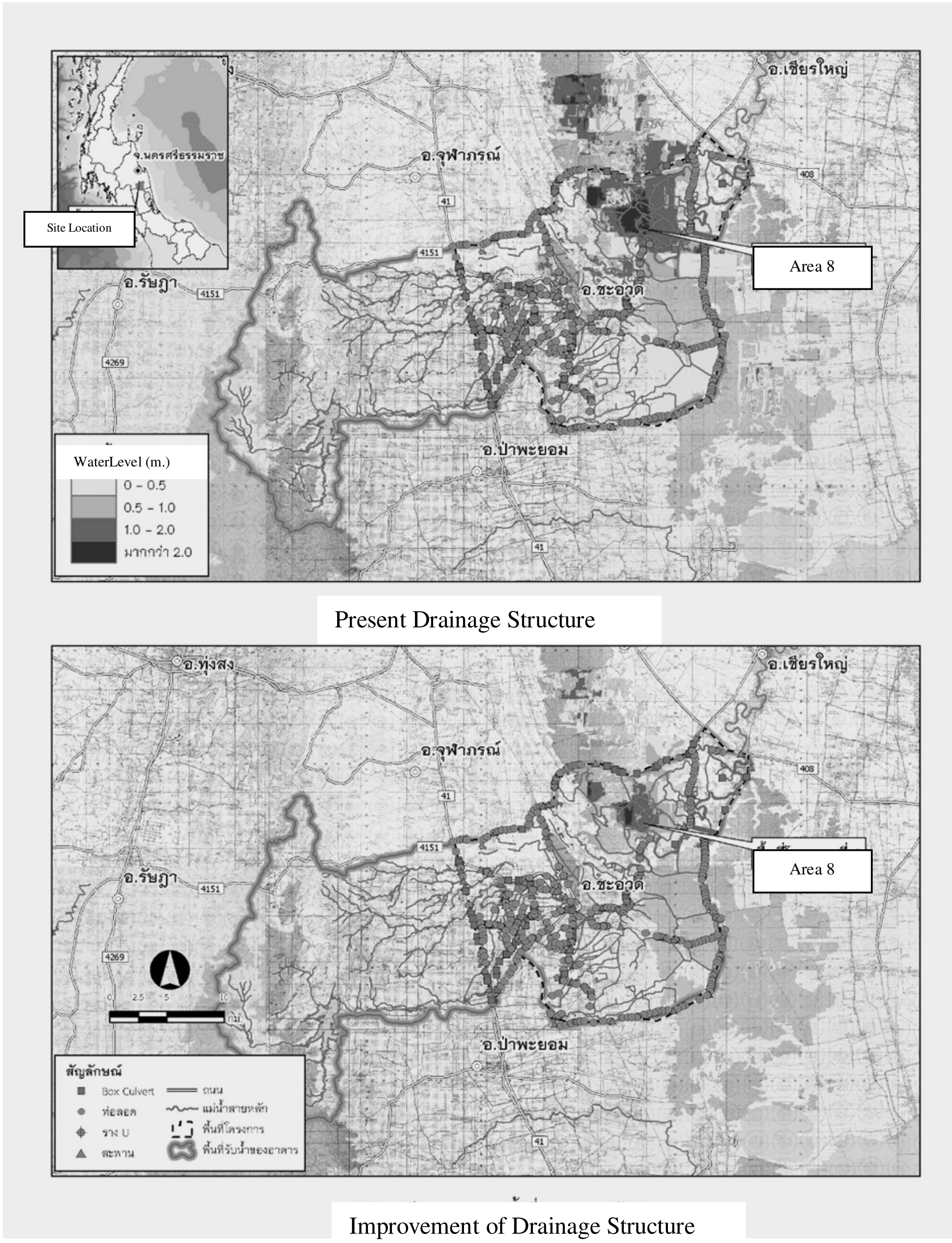
Figure 4 Result Comparisons for Study Area 6



Improvement of Drainage Structure Project

The improvements of drainage structure are design based on the estimated peak runoff rate from developed equations. The new design requires increasing dimension of drainage structure. The result shows thatby increasing dimension of drainage structure, the area of flooding decreases (Figure 5).

Figure 5 Comparison of Flooded area



Financial Analysis

The benefit ofimprovementdrainage structureon road network to relief flood in frequently flooded areas in Southern Thailand isshown in Table 1. The benefit is examined by comparing flooded area before improvement and after improvement of drainage structure. By introducing this project, the total damagedarea can reduce by 64%. The estimated damage cost saving calculating from flooded area reduction is approximately 27.60 million CAD per similar floodevent.

Table 1 Flooded Area Reduction after Improvement

Land Use	Flooded area (sq. km.)		
	Before Improvement	**After Improvement**	**Reduction**
Area 1	52.17	24.99	27.18
Area 3	178.25	96.63	81.62
Area 4	50.75	19.28	31.47
Area 5	103.91	59.65	44.26
Area 8	267.53	21.27	246.26
Area 11	60.27	37.92	22.35
Area 12	100.72	29.90	70.82
Area 13	27.35	13.49	13.85
Total	840.95	303.13	537.82

Conclusions

The current methods of road drainage structure design are normally relied on 4 methods: i.e. Rational Method, Unit Hydrograph, Regional Flood Frequency Analysis, and Synthetic Unit Hydrograph. Such methods have limitations on demanding user's expertise and requiring user tokeep update data according toclimate conditions. To remedy flood problem in frequently flooded areas in Southern Thailand, thus, a new method is introduce to determine maximum flow rate through mathematical model on DEM data (Digital Elevation Model), satellite images, rainfall intensity, soil characteristics, etc. Comparing with the satellite images, this new forecasted flow rate gives more accurate results than that from traditional methods. The improvement of drainage structures is then designed based on these flow rates. Successively, the benefit of this new concept of design is estimated based on the area of flood reducing. The study shows that the benefit of investment from this study can reduce damages around 27.60 million CAD. per similarflood event.

Limitations

The developed peak runoff rate equation which based on physical characteristics of Southern Thailandmay not be suitable for use in other regions of Thailand. The application of this equation on the other regions must then be proved before use.

References

Kasetsart University 2018.The Study of Highways Drainage Structures Design for Alleviating Flood Problems.