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"Water Related Disaster Solutions"

SHERATON MUSTIKA YOGYAKARTA, INDONESIA
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Indonesian Association of Hydraulic Engineers

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Himpunan Ahli Teknik Hidraulik Indonesia (HATHI),
Indonesian Association of Hydraulic Engineers
Secretariat, Gedung Dit. Jend. SDA Kementerian PU
8th Floor, Jl. Pattimura 20, Kebayoran Baru
Jakarta 12110 - Indonesia
Phone/Fax. +62-21 7279 2263
http://www.hathi-pusat.org
email: hathi_pusat@yahoo.com

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PREFACE

The International Seminar with special focus on "Water Related Disaster Solutions" was implemented successfully from 6th to 8th September 2013 in Yogyakarta attended by experts and professionals from many countries including Indonesian as the host.

The discussions of the Seminar had covered the entire aspects of the water related disaster solutions including its risk management, the innovation in disaster mitigation and adaptation, as well capacity building and community participation aspects, involving highly notified professionals with numerous technical models, state of the arts as well as scientific and empirical deliberations.

The overall presentations, discussions and debates during the Seminar concluded that the outputs will undoubtedly contribute to remarkable concepts, strategies, lessons learned, and sharing of experiences on the water related disaster solutions, particularly on the environmentally sound technologies and sustainable practices on the years to come. Based on this fact, I believe that the proceeding of this Seminar will be valuable document for the implementation of the adaptation and mitigation to the climate change.

I would like to thank the organizing committee, peers and writers, seniors and all members of HATHI for enormous supports to the Seminar. May God bless you all.

Dr. Ir. Moch. Amron, M.Sc., PU-SDA

Chairman of HATHI,
September, 2013

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THE EVALUATION OF RETENTION POND CAPACITY UNDER A SERIES OF RAINFALL OCCURENCE AND LAND DEVELOPMENT

Albert Wicaksono* and Doddi Yudianto

Civil Engineering Department, Parahyangan Catholic University

*Email: albert.wcso@gmail.com; Phone: +628122455299

Abstract

A retention pond with total volume of 80,000 m^3 and total area of 1.5 ha was constructed within a residential area in Bandar Lampung in order to protect the area from inundation during high intensity of rainfall. On 24 January 2013 the embankment of pond was found collapsing and caused about 1 m inundation at downstream. This study is aimed at evaluating the reliability of available retention pond to control runoff that flows into it. HEC-HMS model is employed here to simulate the events. Based on the simulation results, it is found that the existing retention pond is able to control the 5 years flood. Another retention pond is necessary to be built at the upstream in case higher return period is considered. Otherwise, outlet with diameter 1 or 1.5 m must be installed to lower the water level within the pond. Moreover, a combination of new retention pond (432,000 m^3) and two culverts with diameter 1 m may increase the capability of available retention pond to cope with 100 years rainfall. To prevent inundation occurs at downstream, construction of dike or normalization is therefore crucial.

Keywords: flood control, retention pond, HEC-HMS

INTRODUCTION

General Background

Retention pond, as one of structural flood protection system, has been widely employed in various land developments. As reported by Wicaksono (2012, 2013), many new developed residential areas or industrial areas are now facilitated with one or more ponds to control the surface runoff. In some cases, it is even supported by pumping system to control water within the retention pond. Referring to that, a retention pond of 80,000 m^3, built in 9.0 m depth with total area of 1.5 ha, was constructed within a residential area in Bandar Lampung. Not only controlling the surface runoff from 35 ha or two third of the developed residential area, the retention pond in fact also serves surface runoff resulted from about 270 ha of bare land which is located at the upper side. At present, the retention pond is generally equipped with 2 culverts which were installed at different elevation. The 50 cm culvert was installed at the pond bottom as main outlet, while the 60 cm culvert which is used as emergency outlet was installed at 7 m above the pond bottom. During heavy rainfall in 3rd week of January 2013, unfortunately, one of the embankments collapsed and caused about 1 m of inundation at the downstream. The collapse of this embankment was believed as result of huge amount of runoff flowing into the pond both from the residential area itself and the upper catchments. Although the embankment has been now completely reconstructed, but it is still necessary to evaluate whether the existing retention pond is able to control such situation. This study is aimed at providing that information including necessary actions as regard to improve the reliability of existing pond.

Location and Data Availability

The study area is administratively located in Kecamatan Teluk Betung Barat, City of Bandar Lampung. As shown in Figure 1 below, it can be noticed that it is located at the upper area in which has a significant contribution of runoff to the downstream. According to the site plan, as presented in Figure 2, the residential area of 57 ha is divided into 9 clusters of housing and 3 clusters of public area. Each area so far has been facilitated with drainage system whereas only clusters A, B, D, and E that contribute runoff to the existing retention pond. As previously mentioned, the existing retention pond also receives runoff from the upper catchment of 270 ha. Although at the moment this upper catchment is in form of bare land, but it is possibly developed in the future and contribute even greater amount of runoff.

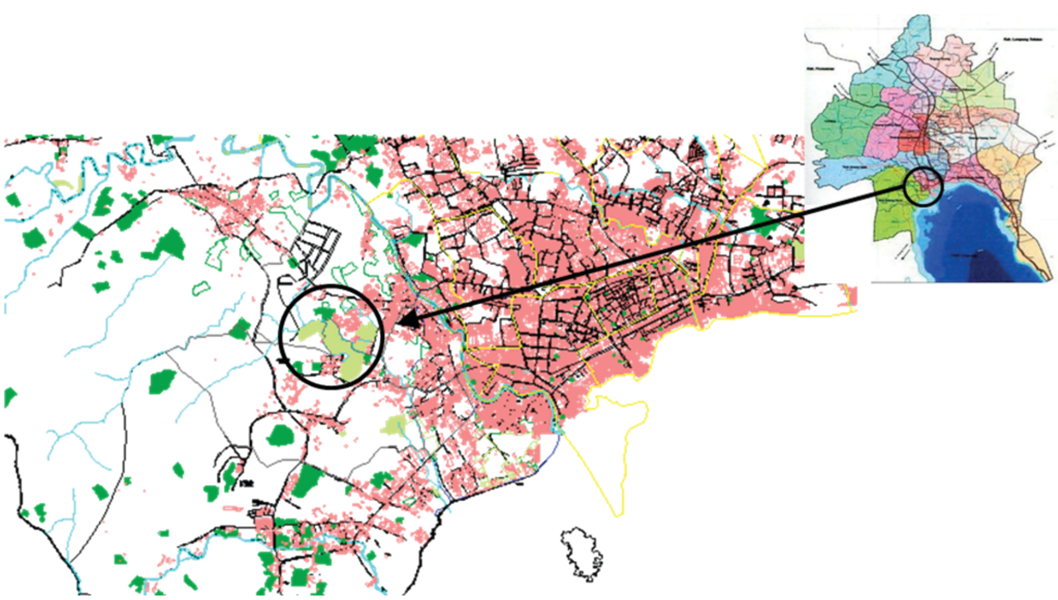

Figure 1. Location of study area

Figure 2. Clustering and existing flow direction

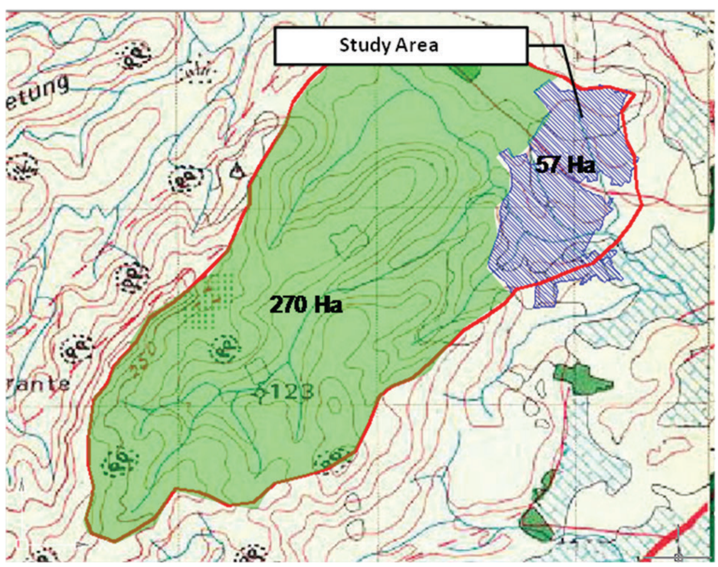

Figure 3. Description of upper catchment

Looking into the rainfall data availability, there are basically three rainfall stations located near to the study location and Sumberejo station in fact is the closest one compared Panjang station and to Polinela station. The total length of data available for stations of Sumberejo, Panjang, and Polinela are 13 years, 14 years, and 5 years respectively. Referring to the collapsing of embankment within the 3rd week of January 2013, some daily rainfall data have also been collected from Sumberejo station. The daily rainfall data collected from 20 – 26 January 2013 are 22, 120, 58, 64, 84, 38, 24 mm respectively.

Methodology of Study

In order to evaluate and further analyses the reliability of existing retention pond to cope with various rainfalls and land development, this study makes use of HEC-HMS (Hydrologic Engineering Center-Hydrologic Modeling System) mathematical model to simulate the events. The analysis is started by the estimation of designed rainfall then continued to rainfall runoff modeling under various schemes as basis to provide alternative problem solutions.

LITERATURE STUDY

Rainfall Frequency Analysis

A hydrological phenomenon is basically a stochastic process. As regard to that, rainfall data should be treated properly to keep its characteristics. To do so, continuous frequency distribution can be employed to describe the data. According to Ponce (1989), there are several continuous probability distributions that can be used for such purposes such as normal distribution, log normal 2 parameters distribution, log normal 3 parameters distribution, Gumbel distribution, Pearson III distribution, and log Pearson III distribution. While Chi-square method and Kolmogorov-Smirnov method are two common methods used to evaluate the best fitted method to real data.

Synthetic Unit Hydrograph Method

Synthetic unit hydrograph is developed for a watershed area and employed to produce storm hydrograph from historical or designed rainfall. Among the available synthetic unit hydrograph methods, Soil Conservation Service (SCS) method is one that widely used in hydrological modeling including in Indonesia. According to Ponce (1989), SCS method is basically a dimensionless unit hydrograph method which is appropriate applied for midsize watershed of 2.5–250 km^2. To represent the influence of variety of land use to hydrograph, SCS method contains Curve Number (CN) as a parameter that depends on land permeability, antecedent soil moisture, and material or vegetation that cover the land.

Probable Maximum Rainfall

Probable Maximum Rainfall (PMP) method of Hersfield is one method that has been commonly used to estimate the value of extreme rainfall. As described in Soemarto (1999), as rainfall is random and unpredictable, this method is therefore completed with some graphics to adjust the variables so that the result is fit to the realistic condition.

RESULTS AND DISCUSSION

Designed Rainfall

According to the Thiessen polygon method, it is found that rainfall intensity at study location can be represented by rainfall observed at Sumberejo station. This means the whole hydrological analysis in this study will be done based on series rainfall data of Sumberejo station. As regard to the designed rainfall estimation, the Kolmogorov-Smirnov method shows that Pearson III contain least deviation to the real data. The estimated designed rainfalls in accordance to this result are 131.50, 156.39, 189.40, 215.20, and 242.10 mm for 5, 10, 25, 50 and 100 years of return period respectively. While referring to the Hersfield method, the estimated PMP and 0.5PMP are 656.79 mm and 328.39 mm respectively.

Designed Flood Discharge

As previously mentioned, the rainfall runoff simulation in this study is conducted using help of HEC-HMS mathematical model. Basically, the model will generate storm hydrograph from single storm events based on unit hydrograph method. To do so, in modeling the rainfall runoff, HEC-HMS has 3 different models: basin model, meteorological model, and control specifications model. While basin model represents the physical conditions of watershed and river as all hydrologic elements are connected here in a network to simulate runoff processes, the meteorological model is used to include the rainfall data. Control specification model, on the other hand, has a role in estimating the time interval of simulation. The detail hydrologic model scheme built in HEC-HMS is presented in the following Figure 4.

As the daily rainfall is assumed to be distributed in 3 hours as 69%, 18% and 13%, the designed flood discharge for each basin at various return periods is presented in Table 1.

Table 1. Designed flood discharge at various return periods

Basin	Designed Discharge (m^3/s)					
	5	10	25	100	1000	0.5PMF
A	2.538	2.102	3.886	5.185	7.636	7.315
B	4.805	2.130	7.486	9.930	14.541	13.937
C	5.662	2.157	8.809	11.677	17.090	16.380
D	0.050	2.183	2.972	0.050	0.050	0.050
E	2.518	2.208	3.933	5.223	7.658	7.338
F1+F2	2.494	2.233	3.841	5.070	7.387	7.083
F3	0.035	2.256	1.064	0.035	0.035	0.035
US1+US2	3.324	2.279	9.116	16.921	37.268	34.202
US3	0.518	2.301	1.459	2.769	6.294	5.762

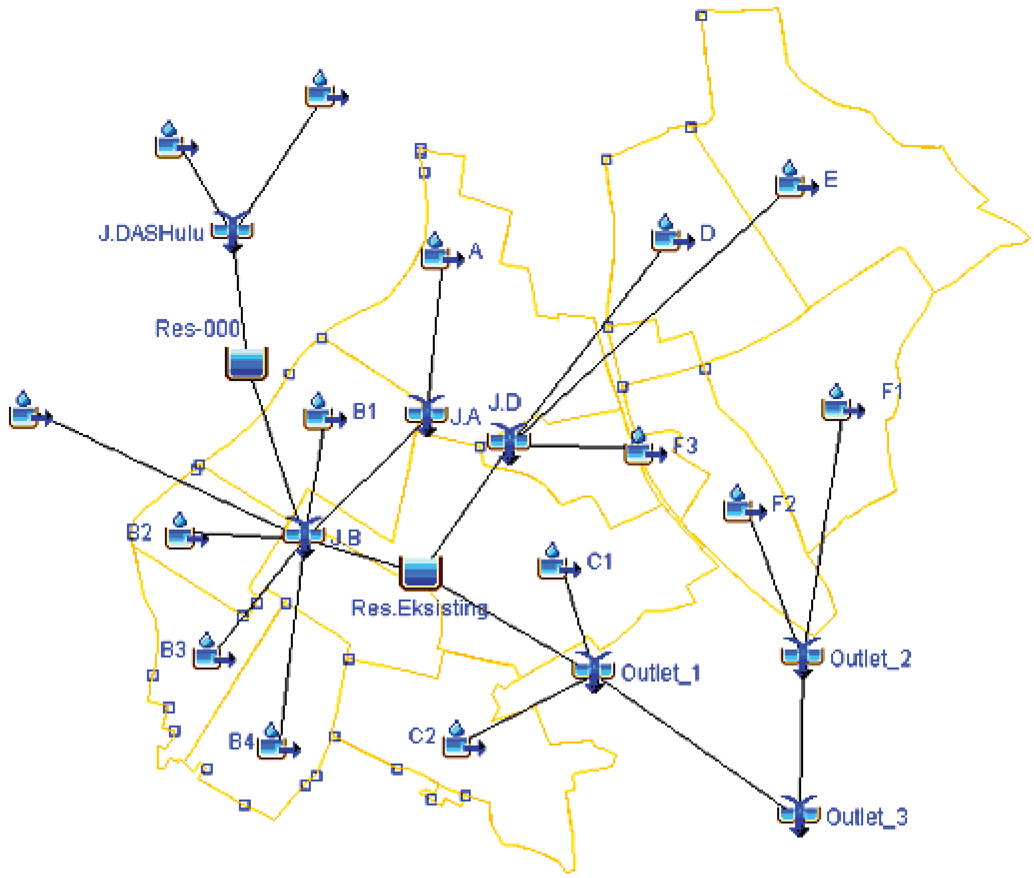

Figure 4. Hydrologic model scheme

Evaluation of Retention Pond Performance in January 2013

As regard to collapsing of embankment in the 3rd week of January 2013, HEC-HMS is used here to model the serial occurrence of filling up the retention pond based on the daily rainfall observed started from 20 – 26 January 2013 as 22, 120, 56, 68, 84, 38, and 24 mm respectively. Based on the simulation results, it is found that on January 24th the water level within the retention pond reached 0.55 m below the embankment crest or at elevation of +18.45 m. This result is basically fit to the obtained site information that stated the embankment was started to collapse when the water level reached less than 1 m below the crest. Both the simulation result and site information have in fact obviously shown that the collapsing of embankment is not caused by overtopping.

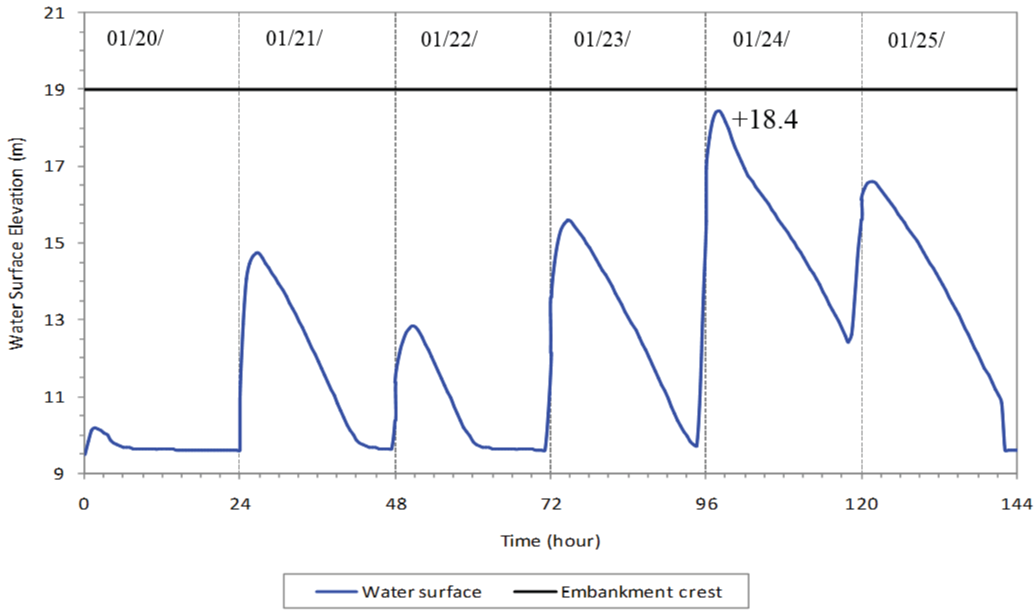

Figure 5. Water surface profile within retention pond (20-25 January 2013)

Evaluation of Capacity of Existing Retention Pond

By assuming that the total capacity of existing retention pond is estimated only up to 1 m below the embankment crest, the effective capacity of that retention pond is about 65,000 m^3 instead of 80,000m^3. Referring to this volume, the simulation result shows that in fact the retention pond is able only to accommodate 5 years of rainfall. Under the 10 years of rainfall, the retention pond will have about 3,339 m^3 of water over spilled. This amount will increase in line with the increment of rainfall. Consider to this situation, addition of new retention pond is necessary.

Required Capacity of Additional Retention Pond

As huge contribution of runoff is given by the upper catchment of 270 ha, ideally, the additional retention pond should be placed at the entrance of study area. Based on the simulation results obtained for present and future development schemes of the upper catchment under various return periods of rainfall, it shows that the required capacity of additional retention pond at least 137,019 m^3 or 2 times greater than the capacity of existing retention pond. Higher return period, as consequence, will enhance to even greater capacity.

Table 2. Required capacity of additional retention pond

No.	Return period	Volume of over spilled (m^3)	Required additional volume (m^3)	
			Present	Future
1	Q2	30,686	0	50,212
2	Q5	68,339	3,339	137,019
3	Q10	103,223	38,223	202,434
4	Q25	158,732	93,732	296,796
5	Q50	207,447	142,447	373,611
6	Q100	262,927	197,927	455,037
7	Q1000	496,683	431,683	767,997
8	Q 0.5PMF	463,122	398,122	726,381

Requirement of Additional Outlets

At present, there are two outlets within the existing retention pond used to control the flood flow. As described in Figure 5 above, about 20 hours is required to get the water level within the pond back to its initial level. Reflecting to this situation, it becomes necessary to have other outlets to accelerate the draining process. Based on the simulation results, ideal elevation for additional outlet is 1.5 m below the emergency outlet. As the 10 years of rainfall will cause the over spilled, another 1 m outlet must be installed to prevent similar disaster. While for higher return periods as 50 and 100 years of rainfall, at least 2 more outlets with 1.5 m diameter each are crucially required. These outlets may reduce the water level to about 0.5-1.0 m; however, it must be accompanied with channel modification at the downstream.

Moreover, combination of additional new retention pond 432,000 m^3 and two outlets with diameter 1 m will increase the ability of existing retention pond to accommodate volume from 100 years return period rainfall. By applying this combination, it can reduce the impact or inundation risk in downstream area.

Channel Modification

The implementation of those solutions above will generally increase the outflow from retention pond. Thus, it is necessary to enlarge the capacity of downstream channel. For village which is located just next to channel may not have sufficient space for channel normalization. Constructing embankment is therefore an alternative that can be applied in this case to increase the channel capacity. Based on the result of hydraulics analysis, it is found that about 1.10 m of levee is required to prevent inundation under 10 years return period rainfall or 1.80 m applied for 100 years of rainfall.

CONCLUSION AND RECOMMENDATION

The existing retention pond is generally able to accommodate 5 years of rainfall. Additional retention pond becomes necessary; however, as the land use is developed to be impermeable. Similarly, additional outlets may help to lower the water level within the existing pond. As consequence, channel modification must be done to prevent inundation at the downstream.

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