International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075, Volume-8, Issue-6C2, April 2019

Effectiveness of Muara Angke Polder System in North Jakarta

Vega Fitria Mutiara Sari, Dwita Sutjiningsih, Evi Anggraheni

Abstract— ***Polder system is a solution for flooding in urban areas where the ground level is lower than the water level of the receiving water body. The effectiveness of the elements such as dike, river channel, pond, drainage canal, and pump station greatly affect the performance of a polder system in controlling water level inside the system. The flood problems that always occur in Jakarta caused damages and losses are the background to conduct an evaluation presented in this paper. Jakarta is the capital city of Indonesia, where the northern part of Jakarta is divided into 43 polder systems and one of them is Muara Angke Polder. This study specifically addresses the Muara Angke Polder system performance. Solving the problem of flood in Muara Angke area should be based on the performance of the existing polder system as one of the flood control elements. This study emphasizes on evaluating the existing Muara Angke Polder system in controlling the flooding. Muara Angke polder catchment area is around 1.46 km2. Daily rainfall data from Kemayoran Station is used to estimate the design flood. Using WinTR-55 model, the performance of polder system is evaluated by comparing the capacity of existing drainage canal, pump and pond to the design flood. The result shows that existing pump and pond capacity in some sub-catchments are inadequate to accommodate the design flood, where the effectiveness is less than 50 %.. The water queue causes overflow in the drainage canal and then flooding in the Muara Angke area is unavoidable.***

Index Terms— ***design flood; flood control; Muara Angke Polder system; performance evaluation***

I. INTRODUCTION

Jakarta is the capital city and the most populous city in Indonesia. Flood always occur in Jakarta due to geographic condition and high rainfall in January and February. The geographic conditions that cause flooding are the location on the coast and traversed by 13 rivers. Population density causes more severe flooding problems such as land cover changes into residential land, uncontrolled waste disposal, sedimentation, reduction capacity of river/canal, and too excessive extraction of ground water that cause land subsidence.

Reference [1] shows one of the Jakarta flood control strategy is polder system. Jakarta is divided into 43 polder systems and one of them is Muara Angke Polder system. Polder system is the solution of flooding in urban areas where the ground level is lower than the water level of the receiving water body. In order to carry out its function effectively, polder system is equipped with a number of elements consisting of dike, riverchannel, pond, drainage canals, and pump station. This study specifically addresses the Muara Angke Polder system located on the coast of Jakarta. Muara Angke Polder system is fullyequipped with all polder elements , however flooding still occurs every year in the polder. Solving the problem of inundation in Muara Angke area should be based on the evaluation of the performance the existing polder system as the flood control measure. The performance should be evaluated as a combination of all elements working on two systems, namely flood protection system and internal water management system [2].

The study aimed to evaluate the performance of the existing Muara Angke Polder system by reviewing and analyzing the existing system. The evaluation is based only on flooding due to runoff of design rainfall for 5-, 10-, and 25-year return period from Kemayoran station, and does not include flood due to tide.

II. MATERIAL AND METHOD

A. Study Area

Muara Angke located at Penjaringan district, North Jakarta. The rate of land subsidence in Pantai Indah Kapuk located in the same district is 84 mm/year [3]. This causes ground level in the area is lower than mean sea level, so the solution of inundation due to rainfall and tideis polder system. Muara Angke Polder is bordered by Java Sea in the north; Karang Polder in the east;Angke Bawah Polder in the south; and Pantai Indah Kapuk Polder in the west. The map of catchment boundary of Muara Angke Polder is presented in Fig 1.

Catchment area of Muara Angke Polder is around 1.46 km^2. In this study the catchment area is divided into 6 sub-catchments based on the existing condition of the drainage system in the polder. The existing drainage system of Muara Angke is as follows and presented in Fig. 2:

- Sub-catchment 1 is pumped to Kali Adem. Pump capacity is 1.94 cms. Pump is built and managed by communities.
- Sub-catchment 2 is pumped to Kali Adem. Pump capacity is 1.05 cms. Pump is built and managed by communities.
- Sub-catchment 3 is pumped to Kali Asin then flow through Gendong Kali Adem channel, and then pumped to Kali Adem by Muara Angke pump station. Pump capacity is 1.4 cms. Pump is built and managed by communities. Muara Angke pump capacity is 2 cms and pond capacity is 16,000 m^3, they are built and managed by the local government.

Revised Manuscript Received on April 15, 2019.

Vega Fitria Mutiara Sari, Civil Engineering Department University of Indonesia, Indonesia (fitriavega@gmail.com)

Dwita Sutjiningsih, Civil Engineering Department University of Indonesia, Indonesia (dwita.sutjiningsih@ui.ac.id)

Evi Anggraheni, Civil Engineering Department University of Indonesia, Indonesia. (evi.anggraheni@gmail.com)

- Sub-catchment 4 is pumped to Kali Asin then flow through Gendong Kali Adem channel, and then pumped to Kali Adem by Muara Angke pump station as well. Pump capacity is 4.1 cms. Pump is built and managed by communities.
- Sub-catchment 5 is pumped directly to the sea. Pump capacity is 0.4 cms. Pump is built and managed by communities.
- Sub-catchment 6 is pumped to Kali Adem. Pump capacity is 2 cms and pond capacity is 16,000 m^3, built and managed by the local government.

Main drainage canal for each Sub-catchment are tabulated in Table. 1.

Table 1. Muara Angke Sub-cathments.

Sub catchment	Area (km^2)	Main Drainage Canal
SC 1	0.28	Pluit Karang Indah
SC 2	0.07	Saluran Pluit Karang Asri
SC 3	0.12	Saluran Pluit Karang Asri
SC 4	0.28	Pluit Karang Barat
SC 5	0.08	Pluit Karang Utara
SC 6	0.63	Gendong Kali Adem

Fig. 1 Catchment boundary of Muara Angke Polder.

B. Design Rainfall

Daily rainfall data from Kemayoran station during 1998 – 2017 is used to be the main data to estimate design rainfall. January and February has the highest average daily rainfall, and the highest is in February 2015 as much as 278 mm/day. The distribution of maximum daily rainfall follows distribution of Log Normal with the calculated coefficient of variety is equal to 0.357. The consistency test is done using Chi-Squared and Smirnov Kolmogorov. The calculated X^2 (1.0) is less than critical Chi-Squared X^2Cr (5.99), and the calculated Do (0.064) is less than critical D (0.29) for Smirnov Kolmogorov, which mean distribution of Log Normal can be accepted. Therefore, the design rainfall is computed using Log Normal distribution. Design rainfall is calculated for return period of 5-, 10-, and 25-year. According to [4] the design rainfall is multiplied by the Area Reduction Factor of 0.994. The complete results are tabulated in Table 2.

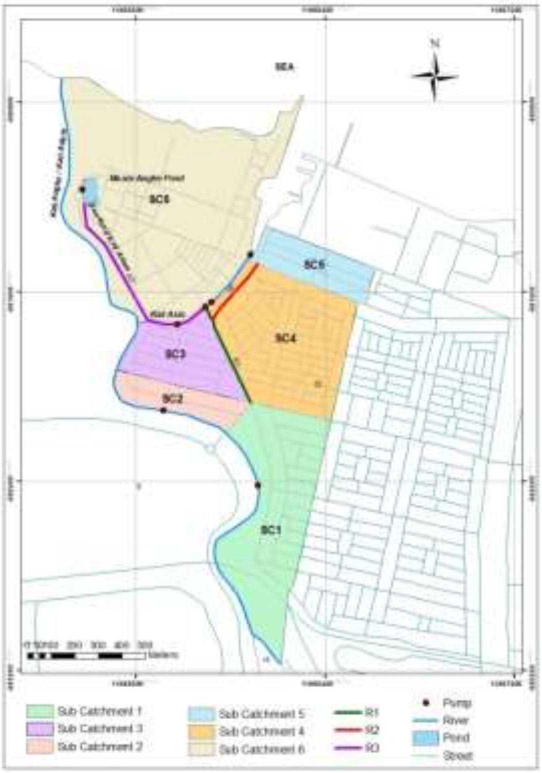


Fig. 2 Existing drainage system of Muara Angke Polder.

Table 2. Design Rainfall for Muara Angke Catchment Area

Return Period (year)	Design Rainfall (mm/day)
5	187.5
10	219.3
25	259.0

A. Design Flood

Estimation of the design flood is using WinTR-55 model. The input data as parameter of the model are sub-catchment properties, reach flow path, rainfall distribution, and design rainfall. Sub-catchment properties consist of area, weighted CN and time concentration (tc)) are tabulated in Table 3. The estimation of weighted CN based on land cover map 2017 and presented in Fig. 3. Time of concentration (tc) is calculated based on the longest flow path and terrain and/or channel slope of each sub-catchment. Reach flow path based on existing condition is presented in Fig. 4. Rainfall distribution using percentage of heavy rainfall distribution duration 4 hours in Kemayoran station [5].

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Table 3. Sub-catchment properties for WinTR-55 model.

Sub-catchment	Area (km^2)	Weighted CN	tc (hour)
1	0.28	81	0.388
2	0.07	87	0.345
3	0.12	86	0.371
4	0.28	85	0.538
5	0.08	84	0.352
6	0.63	87	1.505

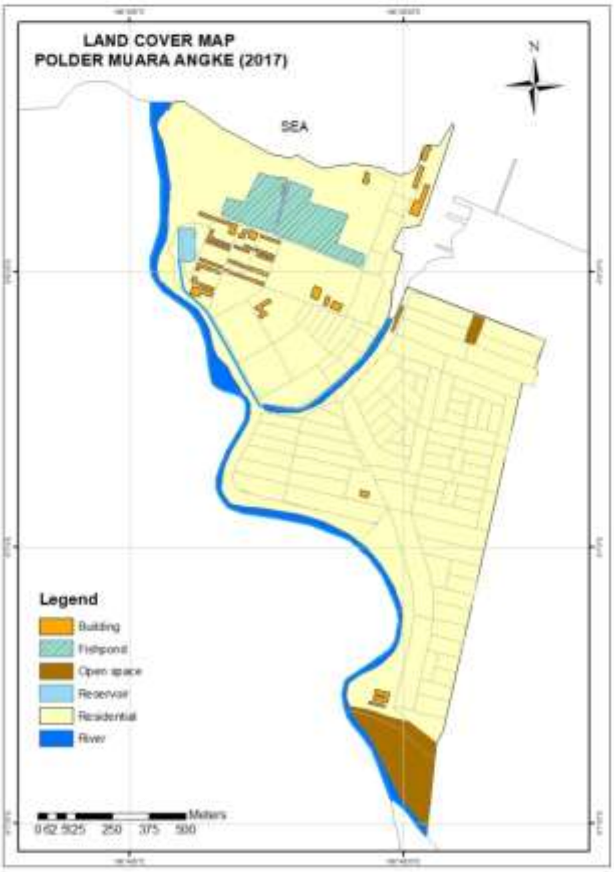


Fig. 3 Land cover map of Muara Angke Polder.

Fig. 4 Reach Flow Path for Win-TR 55 Model of Muara Angke Polder.

B. Evaluation of Polder System

Evaluation of polder system is done by comparing the drainage canal capacity, pump capacity, and pond capacity with the design flood for each sub-catchment according to the existing condition. Drainage canals capacity is calculated using Manning formula [6] as in (1). Drainage canal in the sub-catchments area are concrete, therefore n = 0.012 [6], and side-slope is assumed at 0.001.

$$V = \frac{R^{2/3}S^{1/2}}{n} \qquad (1)$$

Where:
V = flow velocity in the drainage channel (m/s)
R = hydraulic radius = A/P (m)
S = slope (dimensionless)
n = Manning roughness coefficient for various open channel surfaces

The evaluation of pump and pond capacity is done by flood routing [6] based on continuity of mass equation as in (2), and presented in Fig. 5.

$$\frac{dS}{dt} = I(t) - O(t) \qquad (2)$$

Where :
S = storage (m^3)
I = inflow (cms)
O = outflow (cms)

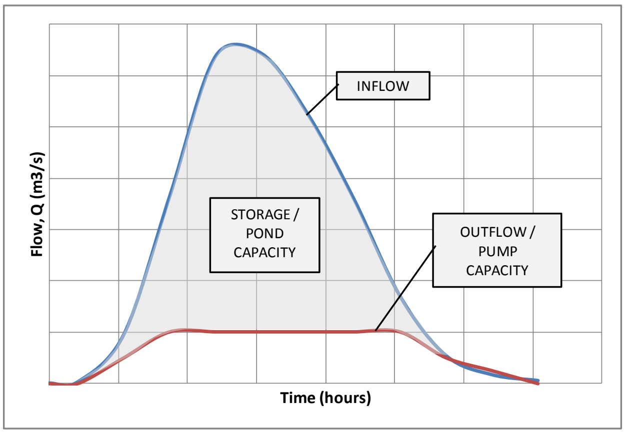
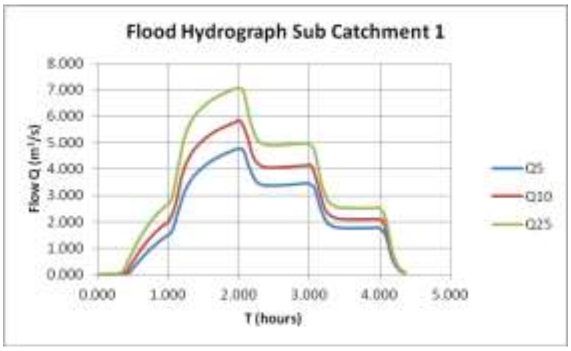


Fig. 5 Change of storage during routing period.

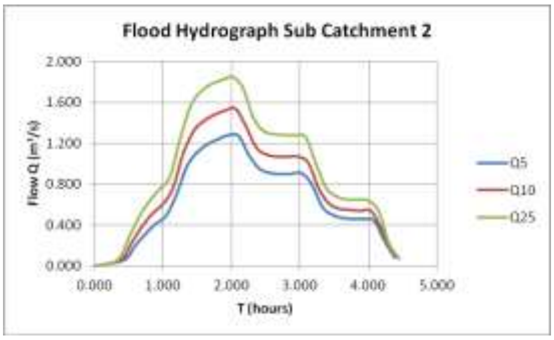
III. RESULT AND DISCUSSION

Flood hydrographs from WinTR-55 model for each sub-catchment is presented in Fig. 6.

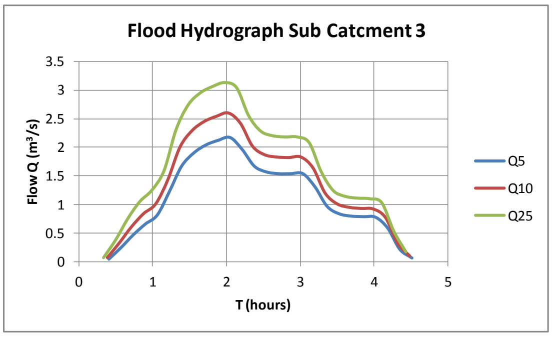


(a)

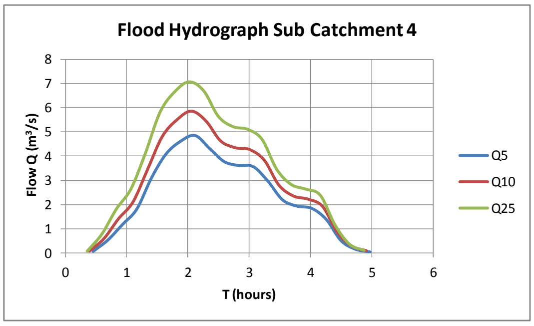
Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication



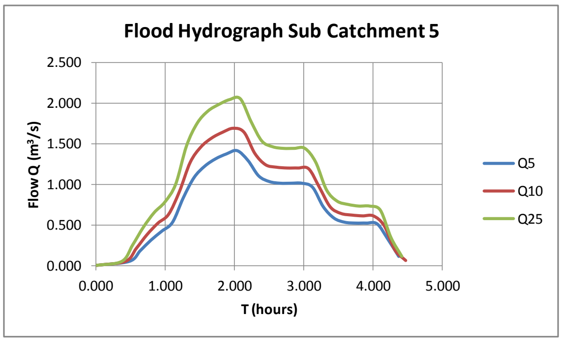
(b)



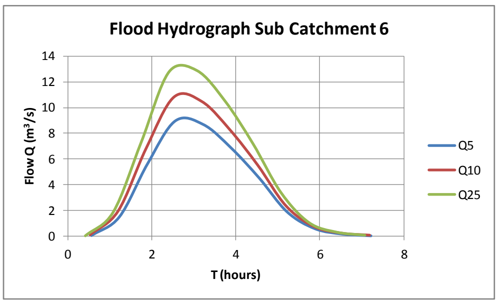
(c)



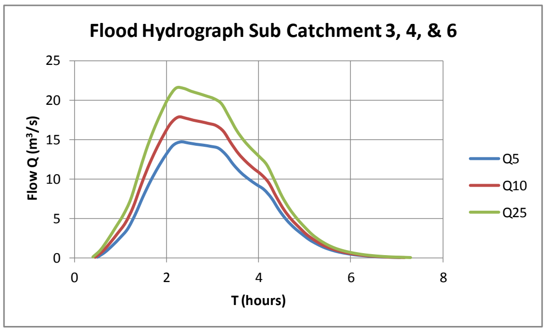
(d)



(e)



(f)



(g)

Fig. 6 Flood hydrograph of Sub-catchment (a) 1; (b) 2; (c) 3; (d) 4; (e) 5; (f) 6; (g) 3, 4 & 6.

The evaluation result of drainage canals capacity is tabulated in Table 4 and Table 5, and the evaluation result of pumps and pond is tabulated in Table 6 and Table 7.

Table 4. Existing drainage channel capacity

Sub-catchment	Flow Velocity in the drainage canal, V (m/s)	Existing drainage canal capacity, Q (cms)
SC 1	1.705	4.348
SC 2	1.743	4.966
SC 3	1.936	6.582
SC 4	1.851	5.663
SC 5	1.339	1.406
SC 6	1.654	18.735
SC 3,4,6	1.654	18.735

Table 5. Drainage canal effectiveness of Muara Angke Polder

Sub Catchment	Flood design (cms)			Effectiveness of canal capacity (%)		
	Q 5	Q 10	Q 25	Q 5	Q 10	Q 25
SC 1	4.66	5.68	6.94	93.30	76.54	62.65
SC 2	1.29	1.54	1.85	100	100	100
SC 3	2.17	2.61	3.14	100	100	100
SC 4	4.86	5.86	7.11	100	96.63	79.64
SC 5	1.41	1.7	2.06	99.69	82.68	68.23
SC 6	9.14	11	13.33	100	100	100
SC 3,4,6	14.75	17.82	21.68	100	100	86.41

Table 6. Existing pumps and pond capacity

Sub-atchment	Existing pump capacity, Q (cms)	Existing pond capacity (m^3)
SC 1	1.94	-
SC 2	1.05	-
SC 3	1.40	-
SC 4	4.10	-
SC 5	0.40	-
SC 6	2.00	16,000
SC 3, 4, 6	2.00	16,000

Table 7. Effectiveness of pump and pond of Muara Angke Polder

Sub-catchment	Flood design (cms)			Effectiveness of pump and pond (%)		
	Q 5	Q 10	Q 25	Q 5	Q 10	Q 25
SC 1	4.66	5.68	6.94	41.63	34.15	27.95
SC 2	1.29	1.54	1.85	81.40	68.18	56.76
SC 3	2.17	2.61	3.14	64.52	53.64	44.59
SC 4	4.86	5.86	7.11	84.36	69.97	57.67
SC 5	1.41	1.7	2.06	28.37	23.53	19.42
SC 6	9.14	11	13.33	77.01	53.80	39.84
SC 3, 4, 6	14.75	17.82	21.68	36.58	27.37	20.67

IV. CONCLUSSION

The evaluation result of Muara Angke Polder system performance shows that effectiveness of pump and pond is range from 59.12 % for 5-year return period, 47.23 % for 10-year return period, and 38.12 % for 25-year return period. While the effectiveness of drainage canals declining from 99 % for 5-year return period, then93.69 % for 10-year return period, and just 85.27 % for 25-year return period. Therefore it can be concluded that inundation in Muara Angke Polder area is caused mainly by ineffectiveness of pumps and pond to accommodate the design flood even for 5-year return period.

Furthermore, it is necessary to study the possible solution to increase the effectiveness of Muara Angke Polder system, so that the performance of Muara Angke polder system can be optimized as flood protection system and internal water management system.

V. ACKNOWLEDGEMENT

The authors express their appreciation as the study was conducted using the research funding for indexed international publication “Hibah Penugasan Publikasi Internasional Terindeks 9 (PIT 9)” fiscal year 2019 granted by Universitas Indonesia.

REFERENCES

1. Nedeco, “Final report, volume 1, river and flood control, drainage management for Jakarta : strategic action program development (DKI 3-9), Western Java environmental management project (WJEMP)”, October 2005.
2. Sawarendro, “Sistem polder dan tanggul laut,” Yogyakarta ILWI, 2010.
3. Djaja, R., Rais, J., Abidin, Z.H., Wedyanto, K, “Land subsidence of Jakarta Metropolitan Area”. 3rd FIG Regional Conference, Jakarta, Indonesia, October 3–7, 2004 (14 pp.).
4. Deltares, “Upper Citarum Basin flood management, annex A 1 D modeling studies analysis of rainfall data,” pp. 31-33, October 2010.
5. Sebastianus Priambodo, “Karakteristik hujan di beberapa stasiun hujan di wilayah DKI Jakarta,” Tesis, Magister water resources management, Universitas Gajahmada, 2004.
6. VT Chow, D.R. Maidment, L.W. Mays, “Applied hydrology,” McGraw-Hill Book Co., Singapore, 1988.
7. Cilcia Kusumastuti, Ruslan Djajadi, and Angel Rumihin, “Evaluation of drainage channels capacity in Ambon city : a case study on Wai Batu Merah watershed flooding,” ScinceDirect. Procedia Engineering, 125, 263-269, 2015.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication