Flood control strategy in waibakul city, central sumba, Indonesia

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Flood control strategy in waibakul city, central sumba, Indonesia

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Abstract. Waibakul City, Central Sumba Regency, East Nusa Tenggara Province, Indonesia is affected by floods every year that comes from overflow of drainage channels. The area of Waibakul is 76, 44 km^2 and dominated by agricultural land. The drainage system is incorporated into the irrigation system, thus forming a complex network of channels. The topography of the area is very flat, with slope (0 to 3) % reaching 78.56% and forming natural basins that are used as rainwater catchment reservoirs. The results of evaluation show that the majority of channel capacity is not roportional to the burden that must be discharged. The reservoir performance is not maximal because the water discharge system only relies on natural water absorption into the soil, so if there is a successive rain then the reservoir is full thus the reservoir control capacity becomes very small. The recommendation for flood control strategies are: (1). Divide the catchment area into sub-catchment areas based on the drainage service area, so the problems can be more easily solved and completed gradually. (2). Increase the capacity of multiple channels. (3). infiltration wells as a means of reservoir water drainage.(4). Control the burden of flood discharge to the office area by making a shotcut. (5). Control the flood water level in rivers that is crossing central office area by making long storage with spillway.

1. Introduction

The urban area of Waibakul Regency of Central Sumba, East Nusa Tenggara Province, Indonesia lies in the valley and mostly (78.56%) has a very flat topography slope (0-3)% [1] Waibakul urban area is 76,44 km2[2] and dominated by productive rice fields that become the mainstay to meet food needs. In some locations, natural hollows are formed that accommodate surface runoff water. Waibakul city drainage system is integrated with its rice field irrigation system, and forms a fairly complex network of channels. Routine floods occur annually in several locations, including central office areas. Flooded puddle is lower agricultural productivity, and disrupt economic activity and service to citizens.

Flat topography and dual function demands on the channel, conditioning the water level elevation on the drain must be maintained so that when functioning as a water irrigation it can flow into the gravity field. This affects the velocity of the water in the channel becomes very low, and the discharge capacity becomes very small. It causes great sedimentation and channel function as the discharge system becomes not maximal. The flood prevention efforts are carried out by utilizing several natural basins as reservoirs of flood waters and improving the condition of some channels. However, the results obtained have not been significant, since the improvement plan has not been based on appropriate strategies and sufficient technical analysis. In this study, the flood control strategy is prepared with a conservation orientation and does not use modern buildings or tools.

2. Methodology

2.1. Concept Development

In efforts to control flood in urban areas is doing an approach which is combination of channel capacity improvement with existing structural optimization efforts to restore natural flow patterns before urbanization [3]. The approach in flood solving in Waibakul urban area is oriented towards: simplification of problems, improvement of flood channeling system performance, and decrease of flood discharge peak. The simplification of the complexity of the channel network system and the extent of the Water Catchment Area (DTA) is solved by dividing the DTA into several Sub-catchments (Sub DTA). The channel network system is also parsed and grouped into each DTA. The results of channel grouping are then used in the evaluation and improvement of channel performance.

2.2. Improvement of Drainage Channel Performance

Efforts to improve channel performance are carried out with the following stages:

1. Calculating flood discharge, which includes analysis of: design rainfall, rain intensity, dirty water discharge estimation, and total flood discharge.
2. Calculating Channel Capacity
3. Conducting Channel Capacity Evaluation
4. Planning changes in channel dimensions and repairing channel walls.

Rain Intensity

Rain intensity is calculated by *Mononobe* formula [4]:

$$I = \frac{R_{24}}{24}\left(\frac{24}{tc}\right)^{2/3} \tag{1}$$

Where:

R_{24} = maximum daily rainfall in 24 hours (mm)
I = rain intensity (mm/h)
tc = concentration time (hours).

$tc = to + ts$

The calculation of *to*for the length of the drainage area of less than 400 m is using the *Kirpich* equation (2):

$$to = 0{,}0195\left(\frac{L}{\sqrt{S}}\right)^{0{,}77} \tag{2}$$

$ts = L/v$

Where:

to = surface run time (minutes)
L = length between the farthest point with the inlet or point being reviewed (m)
S = average slope of ground level
ts = flow time in channel (minutes)
v = flow velocity in channel (m / s)

Surface Runoff

Surface runoff water for DTA less than 0.8 km2 was calculated by rational method [4]:

$$Q = \left(\frac{1}{3{,}6}\right) C.I.A \tag{3}$$

Where:

Q = maximum flood discharge (m^3 / sec)
C = flow coefficient
I = average rainfall intensity during flood time

A = area of drainage (km^2)

Whereas if the area of DTA is more than 0.8 km2, then the equation used [5]:

$$Q = \left(\frac{1}{3,6}\right).Cs.C.I.A \tag{4}$$

$$Cs = \frac{2\,tc}{2tc + ts} \tag{5}$$

Where:
Cs = coefficient of reservoir
tc = concentration time (min)
ts = flow time in channel (minutes)

Channel Capacity
Calculates the channel discharge capacity by multiplying between the flow velocity and the wetness area. In this study, the speed of water flow in channel capacity analysis is used Manning formula. While the channel discharge capacity is calculated by multiplying the flow velocity with the wetness area, as follows:

$$Q = \frac{1}{n}.R^{2/3}.I^{1/2}.A_{sal} \tag{6}$$

Where:
Q = channel discharge capacity (m3 / sec)
A_{sal} = wet cross-sectional area (m2)
R = hydraulic radius (m)
I = channel slope
n = coarse coefficient

Channel performance evaluation
Evaluation of drainage channel performance is usingindicator of sufficiency, that is: if flood Debit (Qb) < discharge capacity (Qk) then channel is given status enough (ckp), and otherwise notenough (t-ckp). The results of evaluation can be seen in the following table:

Channel Capacity Improvement
Dual function channels, as a drainage system and a carrier system (irrigation channels), the water level should be controlled so that water can flow gravityally into the rice field. Therefore the effort to increase channel capacity is done by widening the base and improving the quality of channel wall. The basic widening of the channel aims to increase the area of wetness, while improving the quality of channel wall aims to increase flow speed. Thus, the capacity of channel discharge has increased.

2.3. Improvement of ReservoirPerformance
Reservoir Performance Evaluation
Argue that the reservoir is a vital facility in the surface runoff water management system [6]. In Waibakul urban area, there are many rainwater catchment basins. Large basins and already used as a reservoir are: Situ Lokoujung and Situ Laimaboba. Evaluation of reservoir storage performance used sufficiency indicator, that is: if flood volume (Vb) < storage capacity (Vk) then the reservoir is givenstatus sufficient (ckp), and otherwise notenough (t-ckp).

Improvement of the Reservoir Capacity and the addition of Outlet Facilities
Explains that the spillway door is very influential on the control of water level conditions and flood control capacity of the dam [7]. In the Waibakul drainage system, the reservoir storage capacity is enhanced by expanding the reservoir. To support the performance of reservoirs in anticipation of rainfall, the reservoir is equipped with output facility. There are two types of potential output facilities applied,

namely: (1). Spillway, used in reservoirs located in the locations closed tothe rivers or ravines with elevations below them.(2). absorption wells, to complete the reservoirs located on flat areas. It is a new strategy, and can be suitable to apply in Waibakul area. The capacity of infiltration wells can be calculated with the equation [8][9]:

$$Q = \frac{hF.k}{\left[1 - e^{\left(\frac{FKT}{0,25\pi D^2}\right)}\right]} \quad (7)$$

Where:
Q = Capacity of infiltration wells discharge SNI standard (m^3/second)
H = The depth of standard well storage (m)
T = Flow time (second)
K = Coefficient of land permeabiality(m/second)
D = well diameter

The increasing of infiltration wells capacity and anticipation to the ground water contamination can be conducted by wells digging until reaching aquifer, and byfiltering the infiltrated water. It is also conducted by [10] [11] [12].

2.4. Flood Discharge Controls that is Entering Central Office Area
Central Office Areais the accumulation location of Flood discharge. To reduce the risk of flood, the following efforts are made:

1. the making of flood canal to reduce the Lairabas river dischargeleading to the center of the office area.
2. the making of of *long storage* and spillway to control the influence of reverse water that prevents flow rate in drainage channel in central office area.

3. Results and discussion

3.1 The Making of Sub DTA
Based on the drainage service area, the Waibakul Urban DTA is divided into 3 (three) parts namely DTA 1, DTA 2 and DTA 3. The location of the distribution is described in Figure 1. With the area listed in Table 1.

Table 1. Area of Water Catchment Area

NO	DTA	Wide (Km^2)
1	DTA 2	12.90
2	DTA 1	57.41
3	DTA 3	6.13
	Total	76.44

The results of DTA separation show that all sub DTAs have an area of> 0.8 km2, so in accordance with Saptadji's suggestion, [3] and [4] then flood discharge analysis used Rational equation by taking into account the coefficient of reservoir (Cs).

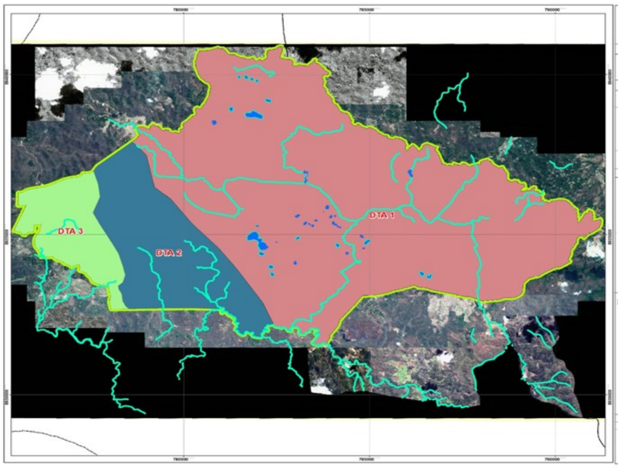

Figure 1. Distribution of Location of Water Catchment Area

The results of channel identification and grouping on each DTA are as follows:

Table 2. List of DTA 1Channels

No	Name of Channel
I.1	Spillway Canal (Umbu Pabal Village)
I.2	Umbu Mamunjuk
I.3	Wairasa (inlet tampungan Lokoujung)
I.4	Wairasa (reservoir outlet)
I.5	Central Government of Ki (reservoir outlet of Lokoujung)
I.6	Central Government ofKa
I.7	Central Government ofKa
I.8	Jl. Waikabubak - Waingapu Km 25 Ka (inlet reservoir of Lokoujung)
I.9	Jl. Waikabubak - Waingapu Km 25 Ka
I.10	Jl. Waikabubak - Waingapu Km 23 Ka
I.11	Jl. Waikabubak - Waingapu Km 22 Ka
I.12	Jl. Waikabubak - Waingapu Km 21 Ka
I.13	Jl. Waikabubak - Waingapu Km 20 Ka
I.14	Jl. Waikabubak - Waingapu Km 18 Ki (reservoir inlet)
I.15	Wairasa irigasi 1 (inlet reservoir of laimaboba)
I.16	Wairasa irigasi 2
I.17	Anakalang irigasi
I.18	Anakalang (outlet reservoir of waitama)
I.19	Matawoga irigasi (inlet reservoir of laimaboba)
I.20	Anakalang (outlet reservoir of Laimaboba)
I.21	Malinjak irrigation
I.22	Malinjak

Table 3. List of DTA 2 Channel

No	Name of Channel
II.1	Jl. Waikabubak - Waingapu Km 16 Ki
II.2	Makateri - Wailawa ka
II.3	Dameka - Wailawa ka
II.4	Wailawa - Malinjak ka
II.5	Dameka irrigation
II.6	Wailawa irrigation

Source: Analysis Result

Table 4. List of DTA 3 Channel

No	Name of Channel
III.1	Jl. Waikabubak - Waingapu Km 14 Ki

Source: Analysis Result

3.2 Improvement of Channel Performance

Channel Performance Evaluation

Based on the analysis of capacity and flood discharge of each channel, channel performance can be evaluated. Check: Table 5 to Table 7).

Table 5. Evaluation of Channels Performance at DTA 1

Id Channel	Discharge (m^3/dt)		Status
	Flood	Capacity	
I.1	78.518	71.208	**t-ckp**
I.2	5.254	31.155	ckp
I.3	3.165	9.029	ckp
I.4	3.697	14.598	ckp
I.5	2.821	0.804	**t-ckp**
I.6	4.724	0.795	**t-ckp**
I.7	6.689	0.327	**t-ckp**
I.8	0.866	0.500	**t-ckp**
I.9	0.384	0.673	ckp
I.10	0.646	1.246	ckp
I.11	0.661	0.734	ckp
I.12	5.324	1.359	**t-ckp**
I.13	7.342	2.804	**t-ckp**
I.14	8.049	2.162	**t-ckp**
I.15	12.396	9.090	**t-ckp**
I.16	4.077	1.802	**t-ckp**
I.17	24.222	7.695	**t-ckp**
I.18	3.325	1.560	**t-ckp**
I.19	8.010	4.207	**t-ckp**
I.20	36.392	3.042	**t-ckp**
I.21	15.070	2.464	**t-ckp**
I.22	4.021	2.861	**t-ckp**

Source: Analysis Result

Table 6. Evaluation of Channels Performance at DTA 3

Id Channel	Discharge (m^3/dt)		Status
	Flood	Capacity	
II.1	6.889	2.897	**t-ckp**
II.2	16.512	5.058	**t-ckp**
II.3	5.651	3.523	**t-ckp**
II.4	8.170	4.377	**t-ckp**
II.5	12.919	2.943	**t-ckp**
II.6	7.652	8.112	**t-ckp**

Source: Analysis Result

Table 7. Evaluation of ChannelsPerformance at DTA 4

Id Channel	Discharge (m^3/dt)		Status
	Flood	Capacity	
III.1.	0.613	3.648	ckp

Source: Analysis Result

Improvement of Channel Capacity

Increasing channel capacity with the status of *t-ckp* is done by widening the channel and installing a channel wall cover. The dimensions of the improvement results are listed in Table 8 to Table 9. Protected layers are in the form of river stone pairs, so the roughness is reduced.

Table 8. Dimensions of DTA 1Drainage Channel Plan

No	Name of Street	Channel Dimensions	
		B (m)	H (m)
I.1	Spillway Canal (S.Lairabas)	15.00	3.00
I.5	Central Government of Ki (outlet reservoir of Lokoujung)	1.50	1.00
I.6	Central Government of Ka	2.00	1.00
I.7	Central Government of Ka	2.50	2.00
I.8	Jl. Waikabubak - Waingapu Km 25 Ka(inlet reservoir of Lokoujung)	1.00	1.00
I.12	Jl. Waikabubak - Waingapu Km 21 Ka	2.00	1.50
I.13	Jl. Waikabubak - Waingapu Km 20 Ka	1.50	1.50
I.14	Jl. Waikabubak - Waingapu Km 18 Ki (inlet reservr)	2.00	1.50
I.15	Wairasa irigasi 1 (inlet reservoir of laimaboba)	3.00	1.50
I.16	Wairasa irrigation 2	2.00	1.50
I.17	Anakalang irrigation	4.00	2.50
I.18	Anakalang (outlet reservoir of waitama)	2.00	1.50
I.19	Matawoga irigasi (inlet reservoir of laimaboba)	3.00	1.50
I.20	Anakalang (outlet reservoir of Laimaboba)	5.00	1.50
I.21	Malinjak irrigation	4.00	2.00
I.22	Malinjak	1.50	1.50

Source: Analysis Result 2017

Table 9. Dimensions of DTA2 Drainage Channel Plan

No	Name of Street	Channel Dimension	
		B (m)	H (m)
II.1	Jl. Waikabubak - Waingapu Km 16 Ki	2.00	2.00
II.2	Makateri - Wailawa ka	2.50	2.00
II.3	Dameka - Wailawa ka	2.00	1.50
II.4	Wailawa - Malinjak ka	2.00	1.50
II.5	Dameka Irigasi	2.50	2.00

Source: Analysis Result 2017

Adequacy Test Results of Channel Capacity Improvement

Adequacy Test Results of Channel Capacity Improvement is done by comparison method between flood discharge and channel capacity after being upgraded; be fulfilled. For more details can be seen in the following Table 10.

Table 10. Evaluation of the Dimensions of the Waibakul Urban Drainage Channel Plan

No	Name of Channel	Qd (m3/dt)	Qk (m3/dt)	Status
I	Water Catchment Area 1			
1	Spillway Canal (S.Lairabas)	40.379	116.912	ckp
2	Umbu Mamunjuk	10.367	31.155	ckp
3	Wairasa (inlet reservoir of Lokoujung)	3.165	9.029	ckp
4	Wairasa (outlet reservoir)	3.697	14.598	ckp
5	Pusat Pemerintahan Ki (outlet reservoir of Lokoujung)	2.821	3.691	ckp
6	Central Government of Ka	4.724	5.397	ckp
7	Central Government of Ka	6.689	7.402	ckp
8	Jl. Waikabubak - Waingapu Km 25 Ka(inlet reservoir of Lokoujung)	0.866	0.906	ckp
9	Jl. Waikabubak - Waingapu Km 25 Ka	0.384	0.932	ckp
10	Jl. Waikabubak - Waingapu Km 23 Ka	0.646	1.246	ckp
11	Jl. Waikabubak - Waingapu Km 22 Ka	0.661	0.734	ckp
12	Jl. Waikabubak - Waingapu Km 21 Ka	5.324	6.035	ckp
13	Jl. Waikabubak - Waingapu Km 20 Ka	7.342	8.268	ckp
14	Jl. Waikabubak - Waingapu Km 18 Ki (inlet reservoir)	8.049	9.599	ckp
15	Wairasa irigasi 1 (inlet reservoir of laimaboba)	12.396	13.031	ckp
16	Wairasa irrigation 2	4.077	6.035	ckp
17	Anakalang irrigation	24.222	28.419	ckp
18	Anakalang (outlet reservoir of waitama)	3.325	4.260	ckp
19	Matawoga irigasi (inlet reservoir of laimaboba)	8.010	12.404	ckp
20	Anakalang (outlet reservoir of Laimaboba)	4.388	5.401	ckp
21	Malinjak irrigation	15.070	15.648	ckp
22	Malinjak	4.021	5.188	ckp
II	Water Catchment Area 2			
1	Jl. Waikabubak - Waingapu Km 16 Ki	6.889	7.514	ckp
2	Makateri - Wailawa ka	16.512	18.042	ckp
3	Dameka - Wailawa ka	5.651	6.388	ckp
4	Wailawa - Malinjak ka	8.170	11.952	ckp
5	Dameka irrigation	12.919	15.808	ckp
6	Wailawa irrigation	7.652	8.112	ckp
III	Water Catchment Area 3			
1	Jl. Waikabubak - Waingapu Km 14 Ki	0.613	3.648	ckp

3.3. Improvement of Reservoir Performance

Evaluation of Reservoir Capacity

The results of evaluation on some of the reservoirs can be seen in the following Table 11 - 12:

Table 11. Evaluation of Lokoujung Reservoir

Hour	Flood Discharge (m^3/sec.)	Vol. Inflow (m^3)	Cumulative Inflow (m^3)	Reservoir Capacity(m^3)	Status
1	4.3	14.509	14.509	71.813	ckp

Source: Analysis Result 2017

Table 12. Evaluation of Laimaboba Reservoir

t	Flood Discharge (m^3/sec.)	Vol. Inflow (m^3)	Cumulative Inflow (m^3)	Reservoir Capacity (m^3)	Cumulative out flow (m^3) (m^3)	Status
2	40.70	146.503	146.503	30.744	115.759	**t-ckp**
3	28.36	102.089	102.089	30.744	71.345	**t-ckp**

Source: Analysis Result 2017

Improvement of Reservoir Capacity
The results show that Laimaboba reservoir capacity does not meet to accommodate rainfall runoff on inlet channels. The effort to improve the storage performance is done by widening the storage area from 16469.56 to 86044.57 m^2.

Added Out let Facility
The reservoir works best if the water level is controllable. This is a major obstacle in the utilization of water basins in drainage and irrigation systems in Waibakul. Water level elevation control cannot be performed, because it is not equipped with adequate system. The water output occurs when the reservoir is full so that the water level is higher than the water level in the drain. When the flow of gravity is stopped, the reservoir is still in near full condition, so if there is rain input again then the reservoir control capacity is relatively small.

Efforts to increase the capacity of the reservoir by expanding the reservoir and deepening the bottom of the reservoir will not be effective in the event of a successive rainfall. Therefore, the strategy to use the absorption well or spillway as a means of water emptied in the reservoir.

Infiltration wells
The use of infiltration wells as a means of discharge of reservoir water is suitable for all situations in drainage Waibakul system. The well is designed so that the reservoir water can be drained away if it is not needed, so that the reservoir control effect on the flood can be maximized. It is chosen with the following considerations:
1. The flow of water takes place in gravity, so the operational is cheaper.
2. The infiltration of water into the soil will also improve the groundwater reserves.

Spillway
Lairabas Channel which is then used as a long storage boils down to a burrow. Water enters the hole and seeps into the soil. The burrow capacity is not predictable certainly, therefore it is equipped with spillway as a means of outlet. Spillway is made on the side of the border between the end of the channel with a ravine downstream with a length dimension of 7 m and a height of 2 m. The spillway peak elevation is made equal to the initial high flood water elevation in long storage, so that when the water in long storage is near full it can flow through the spillway and flow into the gravity abyss. With the spillway, there will be no more overflow in surrounding area. It is also conducted in the dam construction dredged type [11], can see Table 13.

Table 13. Spillway Plan Liang Lairabas River

No	Structure Name	Channel Dimensions		S	A	V	Q
		B (m)	**H (m)**		**(m)**	**(m/dt)**	**(m^3/dt)**
1	Spillway Liang Lairabas River	7.00	2.00	0.0060	14.00	3.64	50.95

Source: Analysis Result 2017

Flood Discharge Control at the Office Center Area
Flood Debit Control at WaibakulOffice Center Area is done by making canals and long storage (Figure 2). Flood canals are intended to reduce the water flow of the Lairabas River which will pass through the office center area. The canal is made by cutting off the Lairabas river line before circling into the territory

of the blast, and is redirected back to the Lairabas river channel downstream. The flood channel is planned to have a rectangular area with a length of 2405 m, a base width of 8 m, and a depth of 3 m. Long storage is made by deepening and widening the Lairabas river line next to the office center area, aiming to control the elevation of the water surface so as not to generate back water in the tributaries that drain water from the office center area. Long storage is planned to be rectangular with dimensions: length 3240 m, base width 15 m, and depth of 3 m.

Figure 2. Canal and Long Storage Plans of Lairabas River

The number of rain in one year in the island of Sumba, East Nusa Tenggara, Indonesia is relatively low (<2000 mm). The land-forming rocks are limestone, so the underground layers tend to be porous. The top layer of clay with a fine texture is so difficult to absorb ground water. This condition causes the availability of water in the dry season is relatively small. Therefore, the conservation of land, reservoir, and efforts to absorb excess water into the soil becomes very important. The limitations of natural conditions bring local policies not to separate between drainage systems and irrigation systems. It is formed by a principled water system: catching rainwater upstream, collecting rainwater in the middle, and utilizing it as a downstream irrigation water. In this case, the natural basin formed by the very flat surface of the land is then used as a water reservoir. The area around the reservoir is very potential to be developed as a means of tourism, to build togetherness of the population in preserving nature and indirectly can improve welfare. It is also recommended in land conservation in the area of \city\batu\East Java [12]. Therefore, the making of infiltration wells becomes very important. Flood control of the Central Office area is done by making a flood channel (shot cut) to control flood discharge. The flood water level elevation in the river in the central office area is controlled by the manufacture of long storage spillway equipped. With such a series of efforts, technically believed to be able to cope with floods without using modern facilities so that the operational costs are relatively cheap.

4. Conclusion

1. The problem of flood in Waibakul Urban Area is quite complicated, because the area of DTA is quite large, and the existing channel network system is mixed between the drainage and irrigation channels.
2. Implementation of controls that have been implemented have not been successful because they have not been based on adequate technical studies.
3. The evaluation results of the existing channel performance indicate that much of its capacity should be improved.
4. The use of natural basin as a reservoir must be equipped with outflow facility
5. Control of flood discharge entering the urban area is done by flood canal drainage in the form of shot cut.
6. Control of the influence of reverse water on the rivers in the area of the office center area is made of long storage which is equipped with spillway.

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