IS RAINWATER HARVESTING THE PERFECT SOLUTION FOR SAWAGUMU VILLAGE - WEST PAPUA?

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Abstract. Sawagumu urban village is one of the flood-prone areas in North Sorong sub-district based on the regional plan 2014-2034 of Sorong City. This region has 3 RW (hamlet) that are severely flooded based on the determination of the priority scales from the Minister of Public Works Regulation number 12 Year-2014 on urban drainage. The Hamlets 03, 04, and 06 were at the top of priority based on the calculation. During the evalution of the drainage channel, there are 27 overflowing channels and 4 not- flowing channels in the affected area. The main causes of overflowing channels based on observation is high discharge, as found is 49% of the total channels, sedimentation of 29%, the presence of waste of 13% and narrowing channels of 9%. To overcome the problems, a rainwater harvesting system is planned as environmentally friendly control to reduce runoff discharge. The principle of the rainwater harvesting is to collect rainwater from the roof, and store in a reservoir using a piping system. In this research, the harvested rainwater is compared with the total runoff to determine the effectiveness of the rainwater harvesting system. Results showed that 53.10-78.81% of the runoff can be reduced using simple rainwater harvesting system.

1. Introduction

1.1 Background

Floods in the Sorong City area often occur in North Sorong District annually. The area is included in the flood-prone area as stated in the spatial plan for the 2014-2034 City of Sorong. The rapid development of urban areas affects the conversion of land that continues to grow to be used as settlements, thus encouraging mining activities of C excavation to meet the needs of building materials such as sand and stone. [1]. Meanwhile, in certain areas such as Sawagumu Urban Village, especially in the centre of the settlements, flooding is caused by inadequate drainage and sedimentation of channels and low public awareness in protecting the environment. Sawagumu village is one of the areas in the sub-district. Based on the calculation adopted the Regulation of the Minister of Public Works and Public Housing No. 12/2014, three hamlets are considered in the first priorities, as they are in severe conditions and require immediate treatment [2]. These 3 hamlets (RW) that were severely affected by floods are RW 03, 04, and 06, which represented by 31 segments of channels spread in the affected RWs. The segments were evaluated by comparing existing dimensions of channel based on the direct measurement on sites to the designated dimensions, which has resulted in 27 overflowing channels and 4 other channels in safe condition.

Conventionally, the overflowing channels are addressed by using channel redesign and normalisation. However, in this research, environmental-friendly drainage control will be applied. These controls have the potential to cause no future environmental impacts. Because it can control the flow of rainwater [3]. Available environmentally friendly drainage can be in the forms of retention, detention and collection. In this research, the collection of rainwater is applied, which the collected rainwater will be used for domestic purposes [4].

In general, rainwater harvesting is an effort to collect rainwater from the roof of a building with the aim of not only to fulfil the domestic needs but also to reduce the runoff that enter the existing channels. This system is also useful to save the cost of redesign and normalization which, as those cost are very expensive. Redesign is one of the controls that change the shape of the initial dimensions into new dimensions based on design criteria. While channel normalization is an attempt to change the initial channel by dredging sediment and garbage methods that can interfere with the distribution of drainage channels [5]. Rainwater harvesting systems require components such as roof as a water catcher, distribution channels, filters, reservoirs, drains and pumps. Then, for the calculation, information on rainfall intensity is also. At the end, the harvest discharge which will later be compared to the total runoff discharge [6].

1.2 Research Purposes

The purpose of planning rainwater harvesting is to reduce the increase in channel discharge, it can be useful as a collection and storage system that can be used for daily needs even as a water reserve when the dry season arrives.

2. Methodology

2.1 Planning Steps

There are several steps that must be taken to plan rainwater harvesting, including:

a) Determine the problematic segment
b) Calculating the area of settlement
c) Identify the type of area surrounded by problem segments based on the type of house
d) Determine runoff coefficient and Rain Intensity based on rainy return period
e) Calculating rainwater harvesting discharge

2.2 Research Sites

The planning area is located in Sawagumu Urban Village, North Sorong District. Due to the area has become the first priority based on the results of scoring from the other three sub-districts using the Minister of Public Works and Public Housing Regulation Number 12 of 2014 (Regulation of the Minister of Public Works and Public Housing Number of 12/2014).

3. Analysis

3.1 Determine the problematic segment of drainage channels

To find out which segment is problematic, it can be reviewed based on the comparison of the dimensions of the planned channel to the existing dimensions obtained from the results of direct measurements in the field.

Based on the results of the evaluation, there were 27 overflowing channels and 4 non-overflowing channels. Therefore, it will be known from the observations after direct measurement that the 27 overflowing channels were caused by several factors such as high discharge, narrowing of the channel, sedimentation, and the presence of garbage. These factors can interfere with the capacity of the drainage channel so that it cannot accommodate runoff water.

Table 1. Problem Drainage Channel Recapitulation (a) and (b)

Streets	Segment	Channel Type	Planning Dimension		Existing Dimension		Length	Description
			H	W	H	W		
			M	m	M	m	M	
RW 06 of Sawagumu Urban Village								
Jalan Arteri	A5-A6	Secondary	1.23	1.74	0.58	0.50	390	Overflowing Channel
	A7-A8	Secondary	1.14	1.10	0.75	0.70	175	Overflowing Channel
	A9-A10	Secondary	1.08	1.12	1.06	1.48	175	Not Overflow
Jalan Handayani	A29-A8	Secondary	0.67	0.84	0.35	1.26	175	Overflowing Channel
	A30-A9	Secondary	0.74	0.97	0.81	0.73	175	Overflowing Channel
Jalan GG 6	A31-A6	Tertiary	1.01	1.37	0.66	0.93	197	Overflowing Channel
	A32-A7	Tertiary	0.77	1.02	0.74	0.92	197	Overflowing Channel
Jalan Sapta Taruna	A5-F1	Secondary	0.73	0.94	0.62	0.55	164	Overflowing Channel
RW 04 of Sawagumu Urban Village								
Jalan Handayani	A20-A27	Secondary	0.62	0.78	0.63	0.75	187	Overflowing Channel
	E2-E4	Secondary	1.29	1.13	0.68	0.61	172	Overflowing Channel
	E6-E8	Secondary	1.26	1.29	0.53	0.58	230	Overflowing Channel
Jalan Tamora	E1-E9	Tertiary	0.46	0.53	0.29	0.36	186	Overflowing Channel
	E10-E7	Tertiary	0.72	0.91	0.35	0.54	340	Overflowing Channel
Jalan GG 4	A28-A27	Tertiary	0.73	0.93	0.37	0.45	322	Overflowing Channel
	E2-E1	Tertiary	0.84	1.11	0.37	0.40	114	Overflowing Channel
RW 03 of Sawagumu Urban Village								
Jalan Sungai Maruni	E8-E7	Secondary	1.20	1.11	1.56	2.17	340	Not Overflow
Jalan Kilang	F1-F2	Tertiary	0.91	1.24	1.13	0.77	313	Overflowing Channel
	F5-B6	Tertiary	1.12	1.20	0.47	0.37	250	Overflowing Channel
	F6-F7	Tertiary	0.66	0.82	0.34	0.66	289	Overflowing Channel
	F10-F11	Tertiary	0.52	0.63	0.46	0.59	105	Overflowing Channel
	F14-B7	Tertiary	0.59	0.74	0.31	0.48	168	Overflowing Channel
Gang kilang Barat	B2-B3	Tertiary	0.52	0.63	0.2	0.38	200	Overflowing Channel
	B4-B5	Tertiary	0.88	1.17	0.36	0.44	200	Overflowing Channel
	F3-F2	Tertiary	0.92	1.23	0.4	0.34	300	Overflowing Channel

Streets	Segment	Channel Type	Planning Dimension		Existing Dimension		Length	Description
			H	W	H	W		
			M	m	M	m	M	
	F4-F5	Tertiary	0.88	1.16	0.4	0.34	300	Overflowing Channel
Gang kilang Timur	F14-F13	Tertiary	0.59	0.73	0.62	0.68	257	Overflowing Channel
	F11-F12	Tertiary	0.70	0.89	0.62	0.68	257	Overflowing Channel
	F10-F9	Tertiary	0.52	0.62	0.42	0.44	265	Overflowing Channel
	F7-F8	Tertiary	0.88	1.17	0.42	0.44	260	Overflowing Channel
Jalan Handayani	B5-B6	Secondary	0.99	1.37	1.44	4.3	626	Not Overflow
	B7-B8	Secondary	1.31	1.28	1.44	1.43	243	Not Overflow

3.2 Calculating surface area

In planning rainwater harvesting, residential area is required. This has a correlation where there are residents taking shelter, that's where there is a roof. The larger the area of settlement in an area, the greater the use of the roof. Where the roof is an important component of the harvesting system. Calculating the area of settlements is obtained from the results of looking at the land use map based on the spatial plan for the 2014-2034 city of Sorong. Then the area and unit numbers are obtained by the Google Earth application

3.3 Identification of type area

Settlements as a place for people to live have a classification based on the type of house used. Due to the type of house will affect the area of the roof as a field of water fall in harvesting rainwater. Based on one of the guide pages for buying a house, the percentage of the area used is as follows:

Table 2. Percentage of Roof Area

Settle ment Type	Buil ding Area	Sur face Area (min)	% Covered Area
Residence	36	60	0.60
Cluster	45	60	0.80

The Sawagumu Urban Village area has various types of houses, so it is necessary to identify the area. Refers to the segment that delimits the region. Then the building is classified into the type of house based on its size.

3.4 Determining runoff coefficient and rain intensity based on rainy return period

The runoff coefficient of the roof used is 0.8-1.0 It aims to calculate water loss due to evaporation and small infiltration from the roof surface. Runoff coefficient can be determined based on population level or assumptions. The intensity of rain used during the 2-year rain return period where the amount of rain is 68.88 mm/hour. This value is obtained from the calculation of the analysis of the intensity of the rain using the Talbot coefficient and the duration of the rain. [7].

3.5 Calculating rainwater harvesting discharge

Rainwater harvesting discharge is calculated using a formula that is still one principle with a rational discharge calculation, which is as follows [8]:

$$Q_P = A \times I \times C \tag{1}$$

Where :
Q_p = harvested Discharge (m^3/s)
A = Area topped (m^2)
I = Rainfall (mm/hour)
C = Runoff Coefficient

The area covered by the roof is calculated from % roof area x residential area in order to obtain the amount of roof that is exposed to rainwater effectively. Then it can also be calculated how much discharge is harvested for each roof with the following formula:

$$\text{Discharge per Roof } (Q_{pa}) = \frac{\text{Qp (m3/s)}}{number\ of\ roofs\ harvested\ (N)} \tag{2}$$

The volume of water that is calculated based on the reservoir used is a tank profile with a capacity of 1100 liters which is sold in the market. After that, the volume can be used to calculate the filling time of the tub where the volume of the reservoir to the discharge per roof produced in seconds.
Meanwhile, the percent of water utilization can be calculated by determining the discharge of the existing channel to the total harvest discharge (Qp) for each overflowing channel. The formula is as follows:

$$\%\ \text{Water utilization} = \frac{\text{Ql (m3/s)}}{Qp\ \text{(m3/s)}} \times 100 \tag{3}$$

Where :
Q_p = harvested Discharge (m^3/s)
Q_l = Channel Discharge (m^3/s)

Although the duration of rain in an area is different, the rational method for calculating the effectiveness of RWH is all the same. This is because the effect of effectiveness does not only depend on the duration of the rain, but also the intensity of the rain. as the principle of rain in the rain return period. The longer the duration of the rain, the smaller the intensity of the rain and the shorter the duration of the rain, the greater the intensity of the rain. The results of the recapitulation of rainwater harvesting calculations can be shown in the **table 3** below.

Table 3. Calculation of Rainwater Harvest in Areas with Problematic Channels (a) and (b)

Segment	Ap	Settlement Type	Roof Area	Roof covered area	House Type	N atap	I	C	Qp		Qpa	V	Time		Ql	% utilized
	m2		%	m^2	m^2	Atap	mm/h		m^3/h	m3/s	m^3/s	m^3	s	m	m^3/s	%
A5-A6	108433	Residence	0.6	65060	36	1807	68.88	0.8	3585	0.996	0.000551	1.1	1996.33	33.27	4.56	21.83
A7-A8	69343	Cluster	0.8	55474	45	1233	68.88	0.8	3057	0.849	0.000689	1.1	1597.06	26.62	9.63	8.82
A29-A8	69343	Cluster	0.8	55474	45	1233	66.88	0.8	2968	0.824	0.000669	1.1	1644.74	27.41	1.07	77.05
A30-A9	46156	Cluster	0.8	36925	45	821	68.88	0.8	2035	0.565	0.000689	1.1	1597.06	26.62	1.40	40.42
A31-A6	108433	Cluster	0.6	65060	45	1446	68.88	0.8	3585	0.996	0.000689	1.1	1597.06	26.62	2.83	35.18
A32-A7	69343	Residence	0.6	41606	36	1156	68.88	0.8	2293	0.637	0.000551	1.1	1996.33	33.27	1.03	61.71
A5-F1	108433	Residence	0.6	65060	36	1807	66.88	0.8	3481	0.967	0.000535	1.1	2055.92	34.27	1.32	73.28
A20-A27	59827	Cluster	0.8	47862	45	1064	66.88	0.8	2561	0.711	0.000669	1.1	1644.74	27.41	0.90	**78.81**
E2-E4	12487	Cluster	0.8	9990	45	222	68.88	0.8	550	0.153	0.000689	1.1	1597.06	26.62	3.36	4.56
E6-E8	40059	Cluster	0.8	32047	45	712	68.88	0.8	1766	0.491	0.000689	1.1	1597.06	26.62	4.79	10.25
E1-E9	12487	Cluster	0.8	9990	45	222	68.88	0.8	550	0.153	0.000689	1.1	1597.06	26.62	0.28	54.89
E10-E7	40059	Cluster	0.8	32047	45	712	68.88	0.8	1766	0.491	0.000689	1.1	1597.06	26.62	0.83	**59.34**
A28-A27	59827	Residence	0.6	35896	36	997	68.88	0.8	1978	0.549	0.000551	1.1	1996.23	33.27	0.87	63.08
E2-E1	12487	Cluster	0.8	9990	45	222	68.88	0.8	550	0.153	0.000689	1.1	1597.06	26.62	1.22	12.49
F1-F2	88946	Residence	0.6	53368	36	1482	68.88	0.8	2941	0.817	0.000551	1.1	1996.33	33.27	1.54	53.10

Segment	**Ap**	**Settlement Type**	**Roof Area**	**Roof covered area**	**House Type**	**N atap**	**I**	**C**	**Qp**		**Qpa**	**V**	**Time**		**Ql**	**% utilized**
	m2		**%**	**m^2**	**m^2**	**Atap**	**mm/h**		**m^3/h**	**m3/s**	**m^3/s**	**m^3**	**s**	**m**	**m^3/s**	**%**
F5-B6	60620	Residence	0.6	36372	36	1010	68.88	0.8	2004	0.557	0.000551	1.1	1996.33	33.27	5.76	9.67
F6-F7	24035	Residence	0.6	14421	36	401	66.85	0.8	771	0.214	0.000535	1.1	2056.87	34.28	0.68	31.73
F10-F11	23902	Cluster	0.8	19122	45	425	66.85	0.8	1023	0.284	0.000668	1.1	1645.49	27.42	0.40	71.76
F14-B7	24753	Cluster	0.8	19802	45	440	70.19	0.8	1112	0.309	0.000702	1.1	1567.28	26.12	0.54	57.15
B2-B3	24753	Cluster	0.8	19802	45	440	70.19	0.8	1112	0.309	0.000702	1.1	1567.28	26.12	0.40	77.89
B4-B5	60620	Cluster	0.8	48496	45	1078	70.19	0.8	2723	0.756	0.000702	1.1	1567.28	26.12	1.37	55.07
F3-F2	88946	Residence	0.6	53368	36	1482	70.19	0.8	2996	0.832	0.000561	1.1	1959.11	32.65	1.51	55.00
F4-F5	60620	Residence	0.6	36372	36	1010	68.88	0.8	2004	0.557	0.000551	1.1	1996.33	33.27	1.35	41.12
F14-F13	24753	Cluster	0.8	19802	45	440	68.88	0.8	1091	0.303	0.000689	1.1	1597.06	26.62	0.54	56.51
F11-F12	23902	Residence	0.6	14341	36	398	66.85	0.8	767	0.213	0.000535	1.1	2056.87	34.28	0.79	26.92
F10-F9	23902	Residence	0.6	14341	36	398	66.85	0.8	767	0.213	0.000535	1.1	2056.87	34.28	0.39	54.73
F7-F8	34031	Residence	0.6	20419	36	567	66.85	0.8	1092	0.303	0.000535	1.1	2056.87	34.28	1.37	22.07

Descriptions : Ap : Settlement Area; I : Rain Intensity; C : runoff 4scoefficient; Qp : Harvested discharge; Qpa : Discharge per roof; Ql : Channel discharge; V : Volume

Based on the results of the above calculation recapitulation of a number of channel segments that have known causes. It is known that there are only 15 effective channels that will be planned for rainwater harvesting, while the other segments can be redesigned and normalized channels. These segments are obtained from the results of channel evaluation. As many as 31 channels of which 27 are categorized as overflowing while the other 4 are not overflowing. The overflowing segment will be handled with a rainwater harvesting system. The discharge of rainwater that is harvested comes from each roof of the residents' settlements, which vary based on the type of their house. The discharge from the roof will be compared with the channel discharge so that it will be known how much the reduction in the runoff of rainwater has occurred in the service area. Based on the calculation results, the lowest is 59.34% and the highest is 78.81% for water that can be reduced or utilized.

The amount of water that is accommodated depends on the intensity and the area covered by the roof. The higher the intensity of rain and the area covered by the roof. So the higher the discharge of rainwater collected. Of course, all of this must be in line with accessories and piping to support the rainwater harvesting system. Accessories such as Stop Faucet, Sock Drat, Water Mur, Letter T, oversock, Elbow, Celfit, PVC glue, pipe clamps and profile sock while the pipes used are vertical and horizontal pipes with various sizes depending on the needs and the intensity of the rain that occurs in that area.

Therefore, it is important to plan for rainwater harvesting to reduce runoff and as a supply of water reserves when the dry season arrives. Not only as a domestic need but also as a system that can save construction costs, so there is no need for all channel segments to be redesigned or normalized which requires very high costs. Although the different drainage control methods are quite diverse. However, the goals are the same to control inundation, drain settlement areas, and reduce new environmental impacts. In order to be a healthy and environmentally friendly city environment will be achieved.

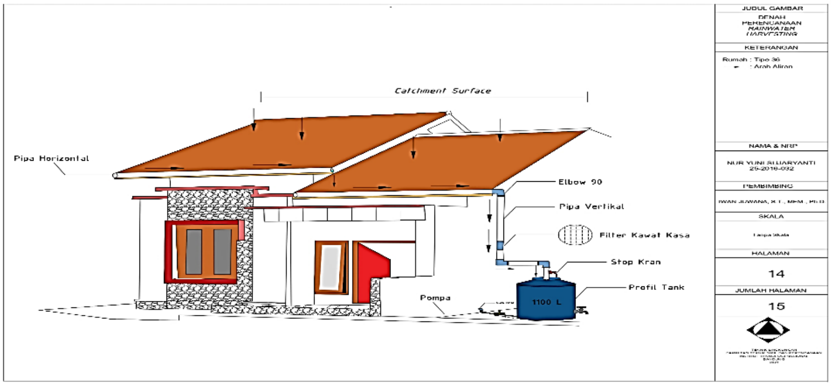

Figure 1. Schematic of type 36 house using RWH

4. Conclusion

If Water harvesting system rainfall that can be applied to Sawagumu village can reduce runoff discharge or water that is utilized to be accommodated in the reservoir by 59.34% to 78.81%.

As much water is accommodated in the reservoir that can be used for domestic purposes. When the dry season arrives, water from this reservoir can be used as a backup source. Therefore, this system can run well if it uses an adequate piping system

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