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Evaluation of Drainage Channel Capacity in Griya Rumbai Lestari Complex, Limbungan Baru Village with EPA SWMM 5.2

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Abstract: The high level of land use to meet the population's needs for land for settlement has led to an increase in land cover which results in high rates of rainwater runoff and reduces the amount of water that experiences infiltration. The study was conducted to review the ability of existing drainage channels to accommodate rainwater runoff and provide technical solutions to overflowing canals. The main components used in planning are rainfall to calculate the design discharge, as well as dimensions of existing drainage, soil infiltration rate test, catchment area, percentage of impermeable area, and soil elevation as the main input data in the drainage capacity simulation using the EPA SWMM 5 tool. 2 and results that the drainage is able to accommodate rainwater runoff. However, the simulation also shows that there are flood points due to higher outfall elevations so that the existing drainage is not able to drain rainwater runoff optimally. Based on this, a rainwater harvesting system (PAH) and infiltration wells are planned as an effort to manage and utilize rainwater runoff by collecting and reabsorbing rainwater runoff into the ground.

Keywords: flood; RWH; infiltration well; SWMM 5.2; land cover.

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1. Introduction

Population growth and rapid urban development create pressure on space and the environment for housing, industrial/service areas, and supporting facilities, which in turn converts open land and/or wetlands into built-up land. Impacted by increasing surface runoff and decreasing the quantity of water that seeps into the ground [1]. This is further supported by the fairly high rainfall in Pekanbaru, namely 57 – 127 mm/day in the last 20 years, so that the relatively flat area of Pekanbaru is less able to bring water quickly to the sewer [2].

The Griya Rumbai Lestari complex is one of the densest settlements in Limbungan Baru Village and a location that is prone to flooding or inundation during the rainy season due to the absence of open land to absorb rainwater runoff. The existing drainage channels do not have a storage capacity that can drain rainwater runoff, so that the channel often overflows causing inundation and flooding.

The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used to simulate single or long-term (sustainable) events by calculating the quantity and quality of runoff mainly from urban areas [4]. The EPA SWMM tool is used in the design flood analysis by taking into account the results of the calculation of planned rainfall, rainwater catchment areas, and existing conditions. The results of the simulation with the EPA SWMM 5.2 device can be in the form of the point where the flood occurs, the volume that overflows from the drainage channel and the length of time the flood occurs.

2. Methodology

The research was carried out at the Griya Rumbai Lestari Complex, measuring the dimensions of the existing drainage and infiltration testing with a double ring infiltrometer 6 times in a span of 1 week to obtain primary data. Secondary data used in the form of rainfall data obtained from BWSS III Riau; contour maps, drainage network maps, and dimensions of the catchment area obtained from the google earth tool; and groundwater depth data which refers to the results of research conducted by [5].

Figure 1. Rumbai Lestari Griya Complex map.

Data processing is done by calculating the infiltration rate with the Horton equation based on the field infiltration rate data that has been obtained. Then the hydrological analysis is carried out by calculating the planned rainfall using rainfall data for the last 20 years. The EPA SWMM 5.2 tool is used in simulating flood points in the catchment area by inputting area data, percentage of impervious area, slope, manning coefficient for subcatchments; channel elevation data at the junction; dimensional data of existing drainage on conduits; and channel elevation data on the outfall.

2.1. Infiltration

Infiltration is defined as the entry of water into the soil surface in a vertical motion through the soil pores. Infiltration has an important role in dividing the defined surface water into surface runoff and subsurface water [6]. Soil infiltration characteristics can be measured by direct measurements in the field and/or when field infiltration data are mathematically fitted to the infiltration model. The direct observation method commonly used to measure soil infiltration is the Double Ring Infiltrometer. Infiltration rate measurements generally use the Horton method. Horton admits that the infiltration capacity decreases with time until it approaches a constant value.

1. Field Measurement Results Data Processing

   Field infiltration can simply be formulated in **Equation (1)**.

   $$\text{Ft}\left(\frac{cm}{menit}\right)=\frac{Depth\ (cm)}{T\ (menit)} \quad (1)$$

2. Data Processing Using Horton's Method

   Horton's method can be formulated in **Equation (2)**.

$$f(t) = Fc + (F0 – Fc) e^{-kt} \quad (2)$$

2.2. Run Off

When the intensity of rain that falls in a watershed exceeds the infiltration capacity of the soil, water will fill the hollows on the ground surface. After the basins are full, then the water will flow over the land surface. Surface run off which is rainwater that flows in the form of a thin layer above the land surface will enter the drainage which then flows into water bodies. If the rainwater discharge is greater than the capacity of the water body to drain the water discharge, an overflow will occur which causes a flood disaster.

2.3. Land Use Change

Land use change is a change in land use from one side of use to another followed by changes in the land function of an area at different times. Changes in the function of land cover from conservation areas (green land) to built-up areas (settlements) will increase the pressure on environmental conditions, among others, affecting the rate of erosion and sedimentation in the upstream area, causing flooding and inundation in the downstream area, as well as landslides and drought [7].

2.4. Hydrological Analysis

3. Rainfall Plan

The log Pearson III method is carried out based on changes in rainfall data into logarithmic form, carried out using **Equation (3)** and **(4)**.

$$\text{Log } Y = \text{Log } x + K\ \text{Slog} \quad (3)$$

$$Xt = 10^{(\log Y)} \quad (4)$$

Where,

Log X = average rainfall value in logs (mm)

K = price obtained based on the value of CS

Slog = standard deviation in log

The Pearson III log method was chosen because of the 4 types of distributions, Pearson III logs do not have special requirements in reviewing the values of ck and cv during statistical calculations.

4. Planned Rain Intensity

Rain intensity is the depth of rainwater or the height of rainwater per unit time. If short-term rain data is not available, only daily rain data is available, then the rainfall intensity can be calculated using the Mononobe formula.

With **Equation (5)**.

$$I = \frac{R24}{24}\left(\frac{24}{tc}\right)^{2/3} \quad (5)$$

With:

I = Rain intensity (mm/hour)

R24 = maximum daily rainfall for 24 hours (mm)

tc = duration of rain / time of concentration (hours)

2.5. EPA SWMM 5.2

The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used to simulate single or long-term (sustainable) events by calculating the quantity and quality of runoff mainly from urban areas [8]. **Figure 2** illustrates how the SWMM visual object collection can be arranged together to describe a rainwater drainage system. These objects can be displayed on a map in the SWMM workspace. The following sections describe each of these objects,

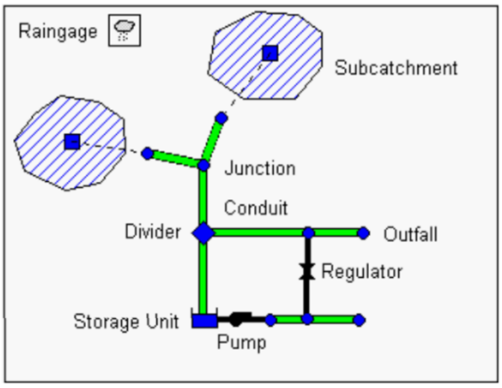

Figure 2. Visual object for drainage system model [8]

5. Rain Gages
   Rain Gages input includes, rainfall data type (intensity, volume, or cumulative volume), time interval (hourly, 15 minutes, etc.), rainfall data source (input time series or external file), name of rainfall data source
6. Subcatchments
   Input subcatchmant includes, outlet node or subcatchment, total area, percent waterproof area, average slope, manning roughness (n), Infiltration rate
7. Junction
   The main input parameters for the Junction are, elevation (channel or channel bottom) and elevation to ground level
8. Conduits
   The main input parameters for coduits are, inlet and outlet node names, elevation above inlet and outlet nodes, channel length, Manning roughness coefficient, cross-sectional geometry
9. Outfall
   The main input parameters for Outfall include elevation and the presence of a closing gate to prevent backflow through the exhaust.

3. Results and Discussion

3.1. Infiltration Rate

The infiltration rate test was carried out at the Griya Rumbai Lestari complex with an area of 14,790 m^2. The test was carried out for 1 week with a total of 6 tests. **Table 1** shows the results of the calculation of the infiltration rate using the Horton method at the Griya Rumbai Lestari Complex. From the calculation results obtained an average infiltration rate of 12.6 cm/hour.

Table 1. Result of Infiltration Calculation at Griya Rumbai Lestari Complex

Information	Unit	1	2	3	4	5	6
F0	cm/hour	19.5	21	22.5	19.5	16.5	18
Fc	cm/hour	3	6	7.5	10.5	9	9
gradient m		-0.024	-0.063	-0.316	-0.0628	-0.0422	-0.043
k		0.056	0.148	0.073	0.145	0.097	0.0993
F Horton	cm/hour	12.775	10,115	14,828	13.0275	12,2022	12.7897

3.2. Rainfall Analysis Plan

The rainfall data used is the maximum daily rainfall data for the last 20 years, namely from 2002 – 2021 which was taken from BWSS III Riau. Rainfall data are used in the analysis of planned rainfall. **Table 2** shows the results of the analysis of planned rainfall,

Table 2. Result of calculation of planned rainfall

Repeat period	Xrt logs	Kt	Slogx	Xt logs	Xt
2	1,947	0.059	0.113	1.9538	89.9081
5	1,947	0.854	0.113	2.04389	110.633
10	1,947	1,233	0.113	2.08683	122.133
25	1,947	1.356	0.113	2.10077	126,116
50	1,947	1,857	0.113	2.15754	143.728

Based on the planned rainfall data that has been obtained, then the data is used in calculating the planned rainfall intensity. In this study, the return period used for tertiary channels with high risk is 5 years. **Table 3** shows the results of the analysis of the planned rainfall intensity.

Table 3. The result of the calculation of the planned rainfall intensity

Repeat Period	Intensity				
	2	5	10	25	50
R24 (mm)	89.90814	110.6333	122.133	126.1162	143.7284
T (minutes)	(mm/hour)	(mm/hour)	(mm/hour)	(mm/hour)	(mm/hour)
60	30.51597	37.55036	41.4535	42.80546	48,78327
120	19.3129	23,76481	26.23502	27.09065	30,87387
180	14.77839	18.18503	20.07526	20.72999	23.62495
240	12.22271	15.04023	16,60357	17.14508	19.5394
300	10.5489	12.98057	14.32983	14.79718	16,86362

3.3. EPA SWMM 5.2

The EPA SWMM 5.2 device is used in calculating the drainage capacity at the research site by entering data on subcatchments, junctions, outfalls, conduits and rain gages obtained from the analysis of rainfall intensity. The data needed are data on area, slope of the area, percentage of impermeable area, manning coefficient, infiltration rate, elevation, and dimensions of the existing drainage. After all data is entered in the program, then run simulation is carried out to see the flood points that occur in the location due to overflowing drainage channels. The related data needed in the SWMM 5.2 simulation can be seen in **Figure 3** for a map of the drainage network in the Griya Rumbai Lestari Complex.

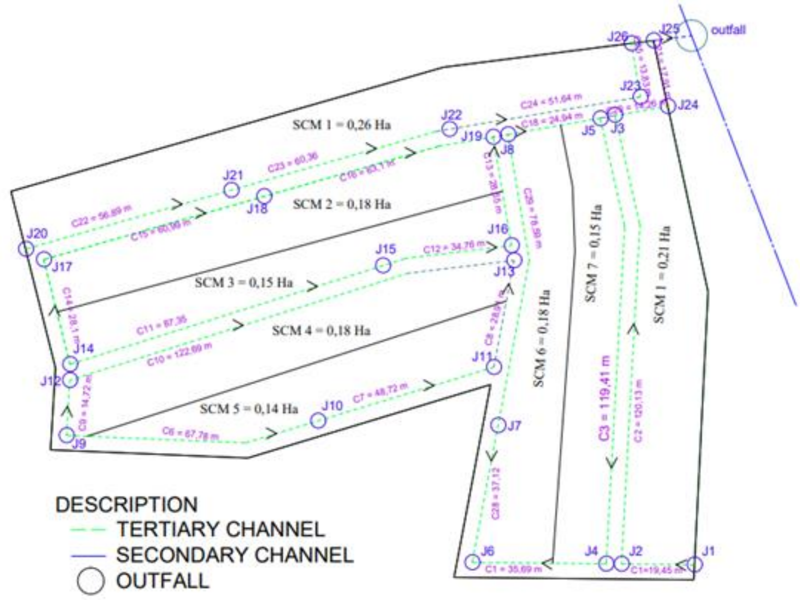

Figure 3. Dimensions of drainage channels at Griya Rumbai Lestari Complex.

Based on the drainage network simulation carried out through the EPA SWMM 5.2 device, the peak spleen discharge rate and drainage channel discharge at the Griya Rumbai Letari Complex can be seen so that it can be seen whether the drainage channel can accommodate rainwater runoff or not.

Figure 4 shows the results of the run simulation on the SWMM 5.2 device, it can be seen that for the peak run off test the yellow subcatchments indicate a fairly high runoff discharge in the catchment area, and the red and green link capacity indicates that there is a channel experiencing runoff, namely channel C28, C7, C8, C12, C15, C12, and C10.

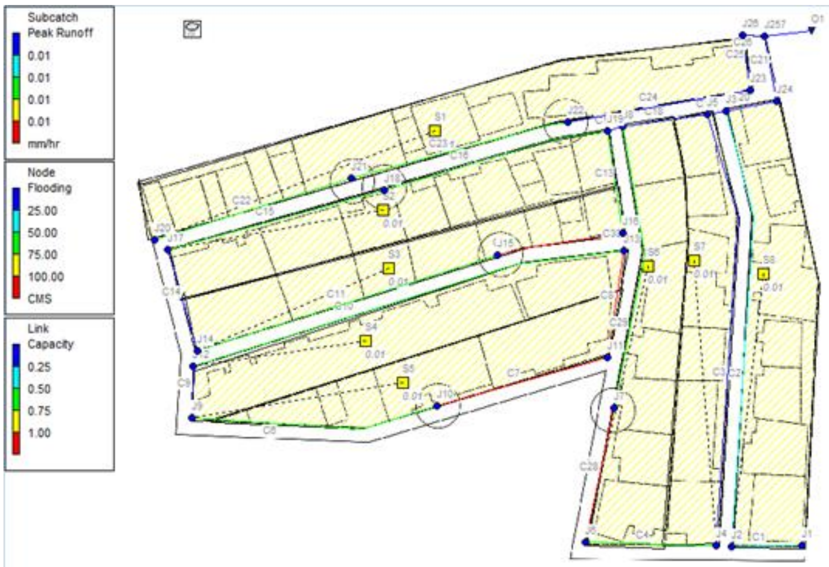

Figure 4. Simulation results at Griya Rumbai Lestari Complex.

In the output results by SWMM, it can also be seen that the comparison number of peak runoff and channel discharges can be seen, so that it can be seen whether the existing drainage channels can drain rainwater runoff. The comparison value of peak discharge and channel discharge can be seen in **Table 4**.

Table 4. Peak and channel discharge output results

Area	Peak Dis-chargecm/s	Channel Dis-chargecm/s	Drainage Capacity
CS. 1	0.01	0.016	Fulfill
CS. 2	0.01	0.014	Fulfill
S. 3	0.01	0.01	Fulfill
CS. 4	0.01	0.012	Fulfill
CS. 5	0.01	0.013	Fulfill
CS. 6	0.01	0.018	Fulfill
CS. 7	0.01	0.012	Fulfill
CS. 8	0.01	0.013	Fulfill

From **Table 4** it can be seen that the drainage channel discharge has a higher number than the peak runoff discharge. However, if we look at the output volume of the share of flooding on the SWMM 5.2 device, it is found that there is runoff of rainwater in the drainage channels in subcatchments 1-7. The results of the output volume share of the flood can be seen in **Table 5**.

Table 5. Flood share volume output results

Area	Total Flood Share Volume (m³)	Duration Flood (Hour)
CS. 1	0.086	4.59
CS. 2	0.067	4.58
CS. 3	0.056	4.55
CS. 4	0.056	4.49
CS. 5	0.061	4.59
CS. 6 & 7	0.123	9.23

Based on the results of the comparison of peak discharge and runoff discharge, it can be seen that the drainage still has sufficient capacity to accommodate rainwater runoff, so it is considered that there are other factors that cause flooding. Based on the simulation carried out using the EPA SWMM 5.2 device, it was found that the water stagnates at a lower point while the outfall of the drainage network is at a higher elevation, so that the drainage cannot work optimally in draining rainwater and makes the water overflow at the lowest elevation point. Another thing that also supports the occurrence of flooding is the percentage of impermeable areas which are much higher than infiltration areas, namely 81.095%. This causes runoff water to not have much opportunity to seep into the ground and cause high surface runoff.

In a study conducted by Huang., et al. [9], SWMM simulation was carried out using actual rainfall data to simulate water level and drainage channel capacity. Rain Water Harvesting is planned as a solution to reduce flood risk by adjusting the quantity and capacity in the SWMM simulation.

3.4 Runoff water conservation analysis

In this study, rainwater harvesting and infiltration wells are planned in all subcatchments that experience flooding by taking into account the capacity of PAHs and infiltration wells needed to accommodate rainwater runoff and calculating the amount of rainwater infiltration that can be absorbed by infiltration wells.

The planned rainwater harvesting is rainwater harvesting by using a 1000 L tank as a storage container, then the infiltration well is planned to be a place for the disposal of rainwater runoff that has been accommodated by PAH. Infiltration wells are planned to be circular in shape with walls made of concrete and the depth of the well is up to 5-6 m.

Based on the flood volume that has been obtained from the EPA SWMM 5.2 device, the calculation can be continued by calculating the PAH storage capacity and infiltration wells based on the dimensions described previously.

Based on the calculation results, it was found that the number of PAH and Infiltration Well needs was found in each subcatchments. PAH technology is used singly in each house and infiltration well technology can be used singly and collectively for 2 houses, this depends on the number of infiltration wells required for each subcatchments.

Table 6. Results of scenario analysis of rainwater harvesting & infiltration wells

No.	Area	Flood Total m^3	Land Area m^2	Jumlah rumah	Storage Volume		Rain Water Harvesting		Infiltration wells		Decription (P = Number of House > Number of RWH and IF)	
					PAH (m^3)	SR (m^3)	Jumlah	V (m^3)	V (m^3)	Jumlah	PAH	SR
1	SC. 1	86	585	10	1	9,591	10	10	76	7,00	✓	✓
2	SC. 2	67	291	10	1	9,591	10	10	57	5,00	✓	✓
3	SC. 3	56	218	10	1	9,591	10	10	46	4,00	✓	✓
4	SC. 4	56	239	10	1	9,591	10	10	46	4,00	✓	✓
5	SC. 5	61	293	10	1	9,591	10	10	51	5,00	✓	✓
6	SC. 6 & 7	123	502	20	1	9,591	20	20	103	10,00	✓	✓
7	SC. 8	0	this area does not require a flood scenario (Best Of SWMM Simulation)									

Khadka., et al. [10] This study demonstrates the importance of maintaining catchment storage during the urbanization process to increase flood resistance and to maintain a more natural water cycle. In addition, the study suggests that storage capacity is an important indicator of flood resilience which is directly related to the physical characteristics of the catchment.

4. Conclusion

Based on the results of the simulation carried out by the EPA SWMM 5.2 device, it was found that 7 subctachmnets experienced flooding from the existing 8 subcatchments. The highest flood volume occurred in subcatchments 6 and 7 with a total flood volume of 123 m^3. flooding occurs due to drainage channels that do not work optimally due to the placement of outfalls that have a higher elevation. So it is planned that 10 PAHs with a tank capacity of 1000 L and 10 infiltration wells with a diameter of 1.5 m and a depth of 5 m are designed to reduce flooding that occurs by increasing infiltration capacity at the point where the overflow occurs.

References

[1] Fizein, I., Istijono, B., & Junaidi, A. (2017). Analysis of the Application of Infiltration Wells to Inundation in the Khatib Sulaiman Area, Padang City. In Andalas Civil Engineering (ACE) Conference 2017.

[2] Suprayogi, I. (2016). Mapping of Flood Vulnerable Areas in Pekanbaru City Using Geographic Information Systems. In Proceedings ACES (Annual Civil Engineering Seminar) (Vol. 1, pp. 257-262).

[3] Wardhana, PN, Yuni, SA, & Kurnia, D. (2018). The Effect of Land Cover Changes on Flood Discharge in the Winongo Watershed, Special Region of Yogyakarta. Scientific Journal of Civil Engineering, 22(2), 157-164.

[4] Lewis A. Rossman and Michelle A. Simon. (2022). Storm Water Management Model User's Manual Version 5.2. Washington, DC: Environmental Protection Agency.

[5] Ramadani, P., Juandi, M., & Malik, U. (2020). Mapping of Potential Underground Water Resources in Rumbai Pesisir District Using the Geoelectrical Method of Schlumberger's Rule. Pharmacy, 12(1), 22-26.

[6] Morbidelli, R., Corradini, C., Saltalippi, C., Flammini, A., Dari, J., & Govindaraju, RS 2018 Rainfall infiltration modeling: A review. Waters, 10(12), 1873.

[7] Warsilan, W. (2019). Impact of Land Use Change on Water Absorption Capacity (Case: Kota Samarinda). Journal of Urban and Regional Development, 15(1), 70-82.

[8] US EPA. 2022 Storm Water Management Model User's Manual Version 5.2 (Seattle: Environmental Protection Agency).

[9] Huang, CL, Hsu, NS, Wei, CC, & Luo, WJ (2015). Optimal spatial design of capacity and quantity of rainwater harvesting systems for urban flood mitigation. Water, 7(9), 5173-5202.

[10] Khadka, A., Kokkonen, T., Niemi, TJ, Lähde, E., Sillanp, N., & Koivusalo, H. (2020). Towards a natural water cycle in urban areas: Rainwater management design modelling. Journal of Urban Water, 17(7), 587-597.