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The Effect of Low Impact Development Implementing on Flood Discharge of Outflow Drainage in the Lakarsantri District Surabaya City

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A B S T R A C T

The drainage system in Lakarsantri District, Surabaya, applies a conventional drainage system which only focuses on water quantity. This is shown by flood events that occur in the area and downstream of the channel. A new paradigm in the management of drainage systems is a low impact development concept that focuses on conservation efforts and the use of natural features to carry out small-scale engineering to control surface runoff of rainwater in watersheds. This research aims to find a good model that can be applied with significant influence. This research was carried out by modeling using the SWMM application with 3 scenarios, scenario 1 Porous Pavement LID, scenario 2 Vegetative Swale LID, scenario 3 50% Porous Pavement + 50% Vegetative Swale LID. The results of the modeling show that scenario 1 has the effect of reducing surface runoff discharge by 0,385 ha-m, which in existing conditions has a surface runoff of 6,574 ha-m and then reducing to 6,189 ha-m with an installation percentage of 2,81% of the total area by the research location.

1. Introduction

In the 21st century, one of the most significant trends is rapid urbanization, this causes disruption of the hydrological cycle in the area, such as an increase in impervious areas [1]. Increasing the impermeable area will prevent rainwater from seeping into the ground, thereby causing an increase in surface runoff. As a result of the increasing population and influencing the climate in the region, it causes a high frequency of extreme weather events [2].

Lakarsantri sub-district is one of the sub-districts in Surabaya with a high incidence of urbanization. In this area, flooding often occurs when the rainy season arrives. The channels in the area overflowed because the drainage channels were unable to accommodate the discharge. This causes puddles along the channel including inundating roads, residential areas, shops, luxury housing, and golf courses [3]. This is because the drainage channels in this area still use a conventional drainage system. Conventional drainage systems focus more on the quantity of

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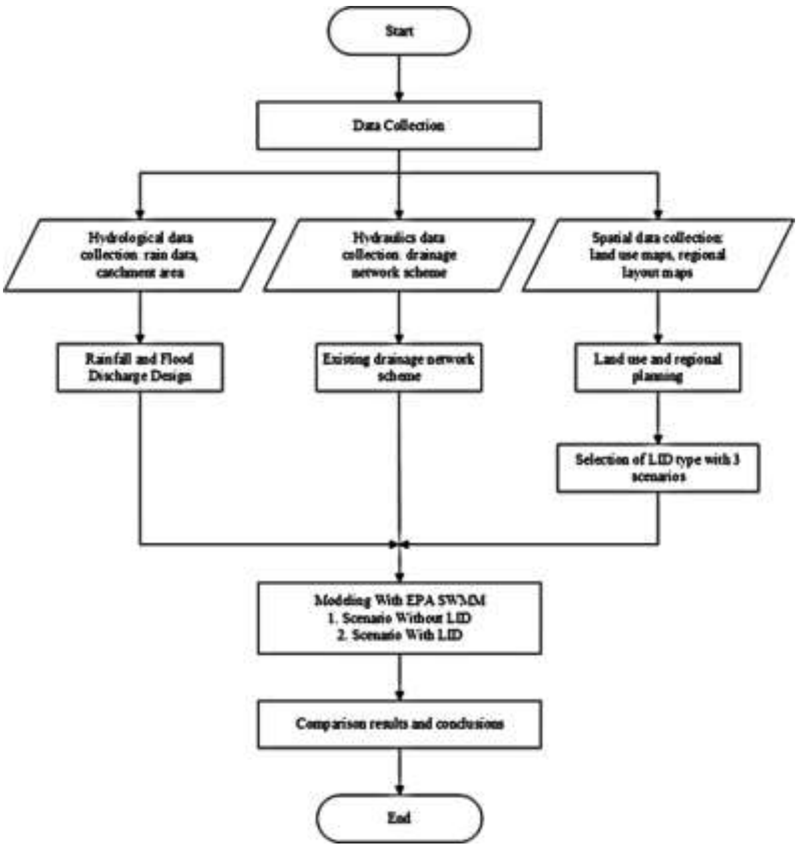
rainwater, even though other aspects are ignored such as water quality, groundwater protection, and the water cycle [2].

Low Impact Development (LID) is an environmental concept-based rainwater management approach, that specifically applies small-scale engineering to control rainwater in watersheds through processes of infiltration, filtering, storage, evaporation, and holding runoff to return it to pre-development conditions [4][2]. Development planning and the LID method approach are directed at managing rainwater runoff and increasing infiltration to reduce surface runoff. LIDs use natural structures to reduce and prevent peaks in runoff which can therefore reduce the impact of flooding. Apart from being environmentally friendly and suitable for sustainable development, LID is generally very cost-effective because the system pays more attention to conservation [5].

To determine the type of alternative LID that can be applied, an analysis was carried out using the EPA SWMM application. This application is an auxiliary program for simulating rain discharge models that can simulate single or long-term events [6]. This LID will be implemented in the Lakarsantri District area, Surabaya City to reduce the runoff water and to obtain a good type of LID that can be applied to that location.

2. Research Method

The stages for LID analysis begin with the data collection stage, therefore, plan what data is needed. Selecting data sources and data types also needs to be done to know which place or agency to go to for data collection. In this research, the data is grouped into Hydrological Data, Hydraulic Data, and Spatial Data. These three data will be analyzed and used as input data for making the model. The entire research process will be carried out through several stages as shown in the research flow chart in Figure 1.



Source: Personal Documentation

Figure 1. Research flow chart.

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3. Description and Technical

3.1 Hydrological Analysis

For analyzing hydrology, rainfall data with a length of 10 years from influential rainfall stations in the region is used. From the results of the rainfall distribution analysis, the Lakarsantri District area is influenced by the Simo Rainfall Station as shown in the Polygon Thiessen map.

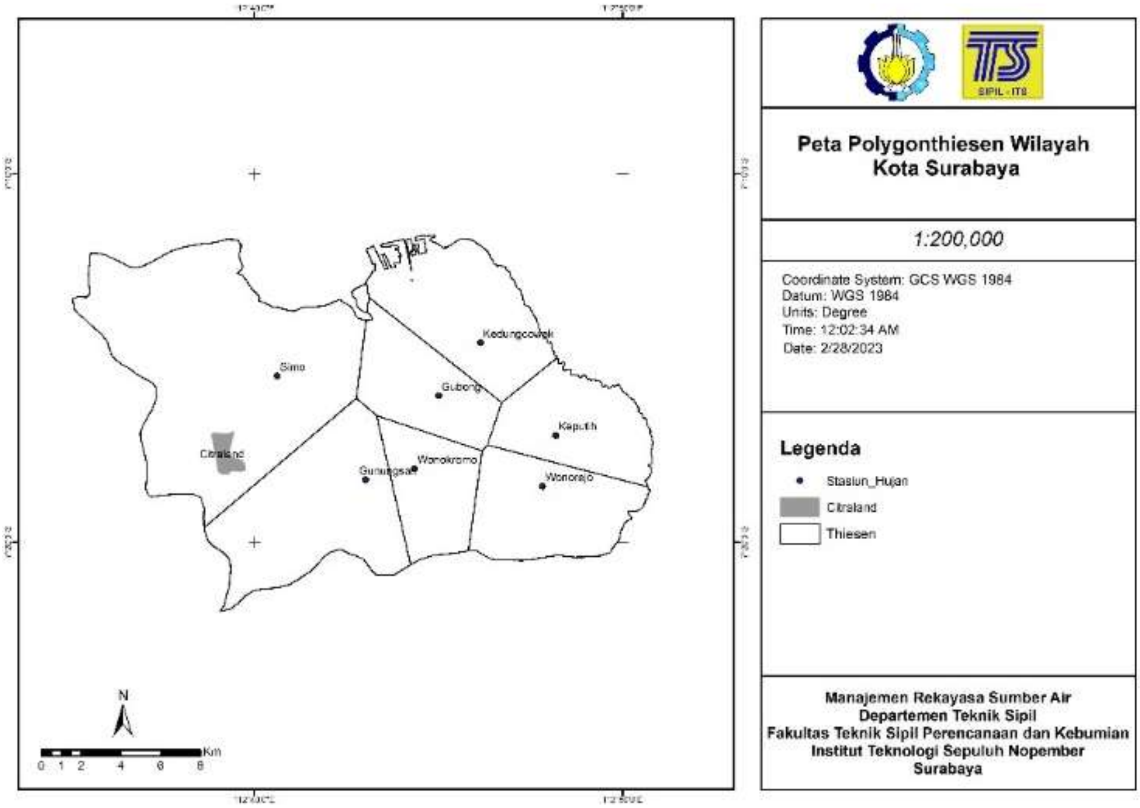

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Figure 2. Polygon thiessen map of research location

Based on the results of statistical parameters data from Simo Rainfall Station, the suitable distributions are the Normal Distribution Method and the Log Pearson III Distribution Method [7][8][9]. For the two distribution methods, Chi – Square Test and Smirnov – Kolmogorov Test were carried out. The result is the Normal Distribution Method qualifies the requirements of the Chi - Square Test and the Smirnov - Kolmogorov Test.

Table 1. Summary result of distribution method suitability test

Distribution Method	Distribution Fit Test	
	Chi - Square	Smirnov - Kolmogorov
Normal	Accepted	Accepted
Log Pearson III	Not Accepted	Accepted

Source : Analysis Result

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Table 2. Rain design for Normal Distribution method

Period Years (T)	Kt	Rain Design (Xt)
2	0	80.09
5	0.84	93.89
10	1.28	101.11
25	1.71	108.15
50	2.05	113.76
100	2.33	118.35
1000	3.09	130.84

Source : Analysis Result

After getting the annual rainfall distribution, the data is converted into a centralized rain distribution [10][11] for 5 hours because the rain that occurs in Indonesia usually does not more than 7 hours [12]. The rain design used as input is rain design 10-year return period which is converted into centralized rain for 5 hours as shown in Table 3.

Table 3. Summary result of centralized rain 5 hours

t (hours)	10 th 101.110
1	59.161
2	15.360
3	10.773
4	8.575
5	7.241

Source: Analysis Result

3.2 Hydraulic Analysis

In the hydraulic analysis, drainage network schematic map data is used, which contains network schematic data and channel elevations. The network schema is used to determine nodes, conduits, and outfalls. The results, there are 91 nodes, 98 conduits, and 1 outfall.

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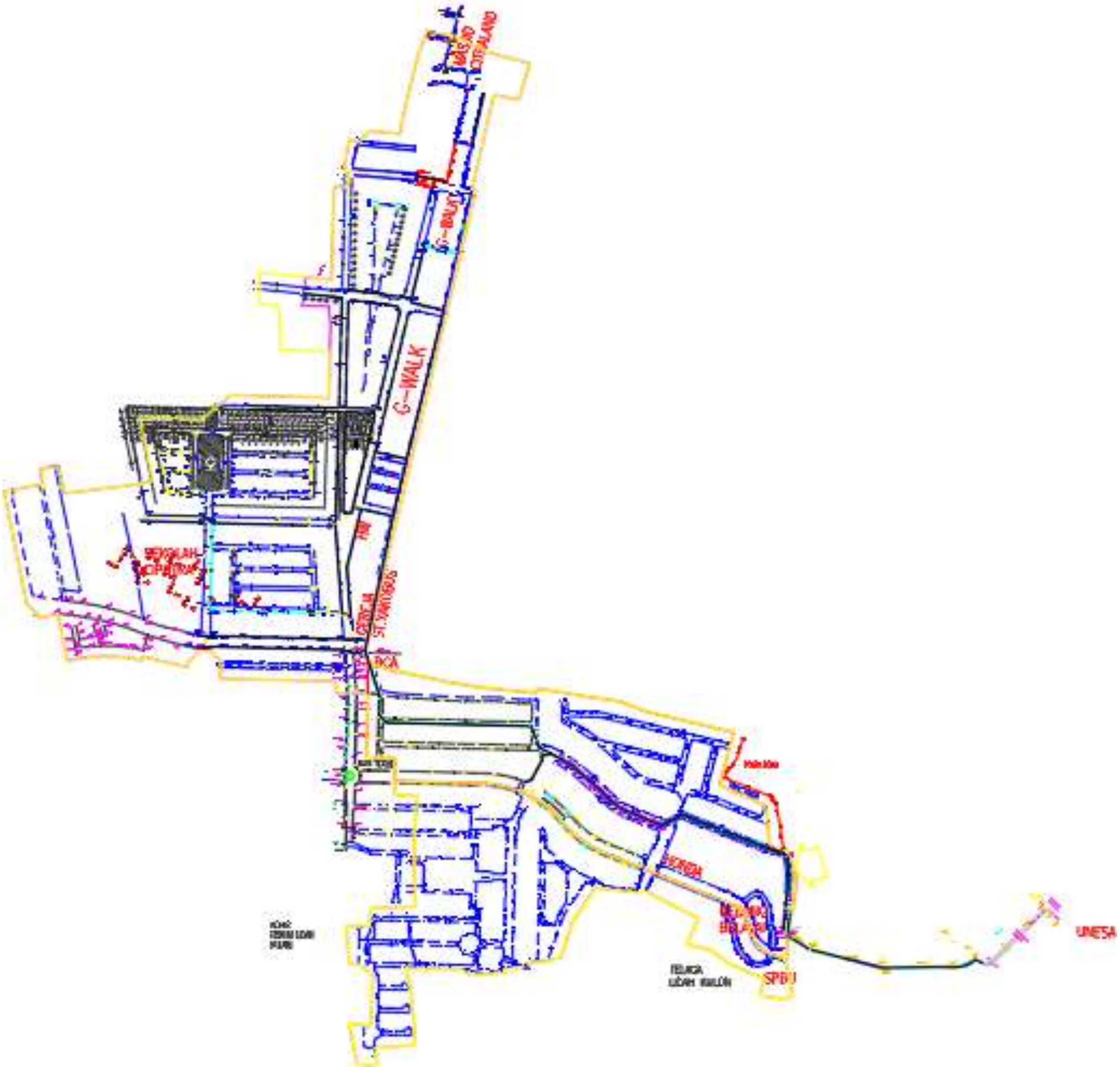

Source : Personal Documentation

Figure 3. Drainage network scheme of research location

3.3 Spatial Analysis

The spatial data used is the latest terrain image map at the research location. This data used as an overlay layer on the drainage network scheme to determine sub-catchments, and also will processed into a land use distribution map that will be used to select LID locations. The result, 43 sub catchments and land use maps were obtained as in Figure 4 and Figure 5.

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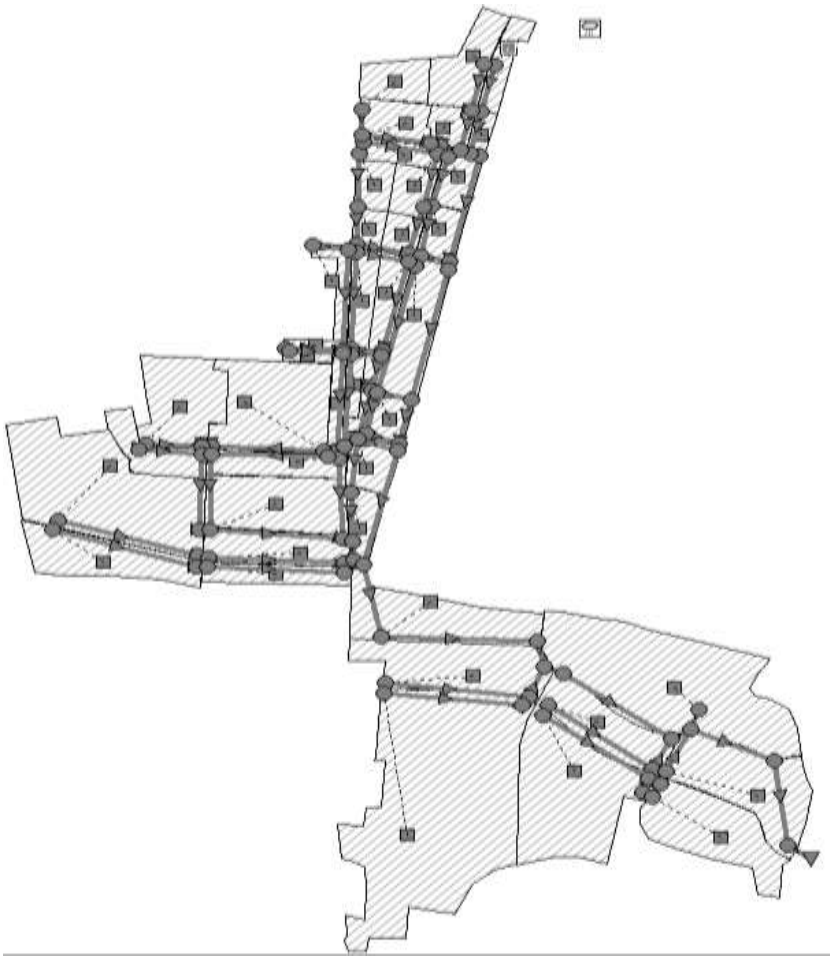
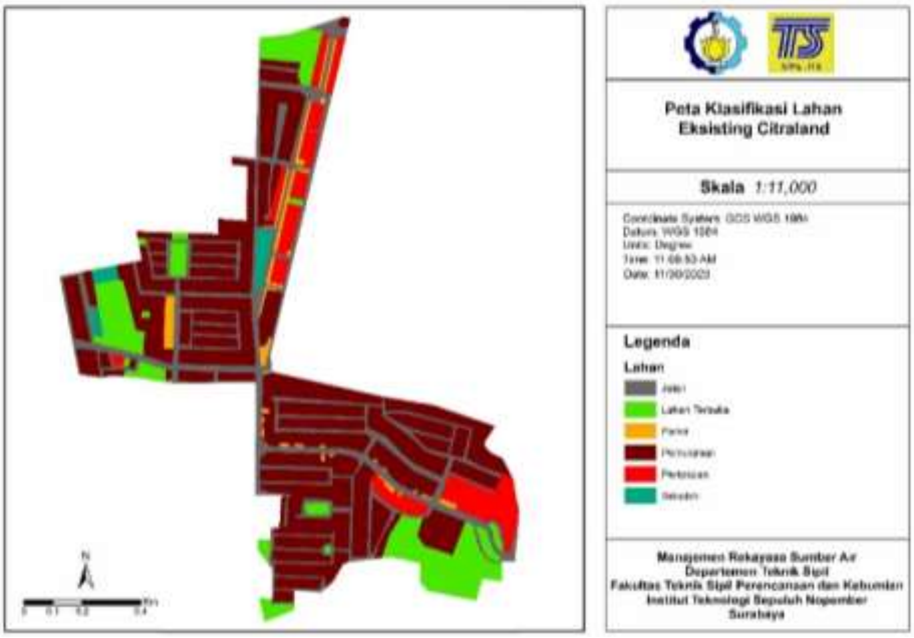


Source : Analysis result
Figure 4. Modelling result in SWMM



Source : Analysis result
Figure 5. Land use distribution map of research location

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3.4 SWMM Data Input

After obtaining data from the analysis, it will be input into the model object for simulation [13]. SWMM is software that requires input of values and parameters to run rainfall - runoff simulations [14]. The following description of each input parameter object:

1. Rain Gage

   In this object, rainfall data which will be used for simulation is entered. The rainfall data used is hourly rainfall which is the result of hydrological analysis in the form of a time series [15].
2. Subcatchment

   input for this object is data related to the land at the location. As in Figure 4. the location has been divided into several subcatchments. Some of the input data required are the outlet of the land, area, slope of the land, percentage of impervious land, and the infiltration method [15].
3. Node / Junction

   Input for this object is the hydraulics data which is contained in the drainage network schema data. The node/junction in this simulation describes the connecting point between channels and also the place or point to receive flow from the sub-catchment being measured [16]. Some of the input data required are elevation, max depth, initial depth, etc. The node / junction at the end of the channel in this simulation is the final drain which is determined using the outfall type [15].
4. Conduit

   Input for this object is the hydraulics data which is contained in the drainage network schema data. The conduit in this simulation can be called a carrier channel. Some of the input data required are channel shape, channel length, Manning coefficient, and max depth [15].

3.5 LID Scenario

Design LID control usage is carried out based on sub-watershed or sub-catchment characteristics like land use, area, slope, and impervious area [17][18]. In this research, the implementation of LID will be designed in 3 scenarios based on the characteristics and type of land use regarding feasibility and ease of installation. The 3 scenarios are LID PP (Porous Pavement) for scenario 1, LID VS (Vegetative Swale) for scenario 2, and a combination of 50% PP (Porous Pavement) and 50% VS (Vegetative Swale) for scenario 3.

PP (Porous Pavement) is integrated into parking lots and sidewalks to capture runoff from surrounding impermeable surfaces in a single sub-cathment. PP uses infiltration-based technology, which allows runoff water to flow into the open-graded aggregate subbase layer. This layer allows water to seep into the soil [19]. VS (Vegetative Swale) is a network of canals with sloping sides surrounded by vegetation, built in small grassy areas to collect rainwater from the road [20]. This LID uses infiltration-based technology, and temporarily holds water and drains the water. These two LIDs were installed at available locations taking into consideration land use in the sub-cathment area. Details of LID location can be seen in Figure 6 and Figure 7.

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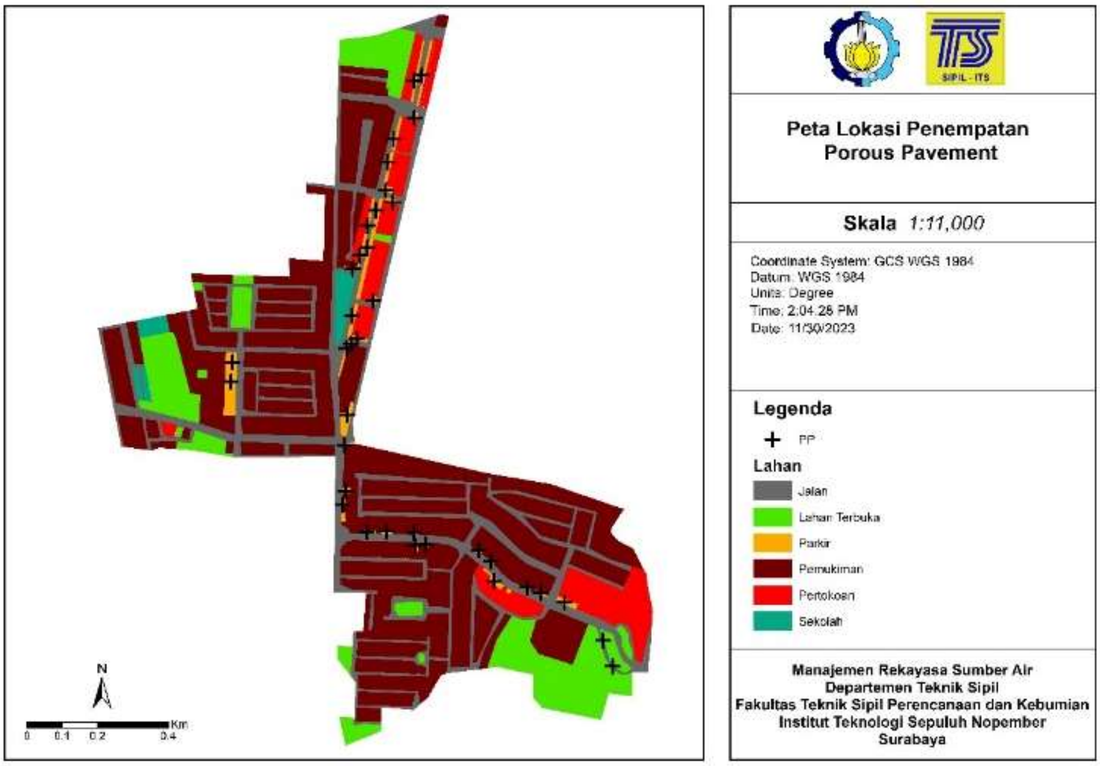
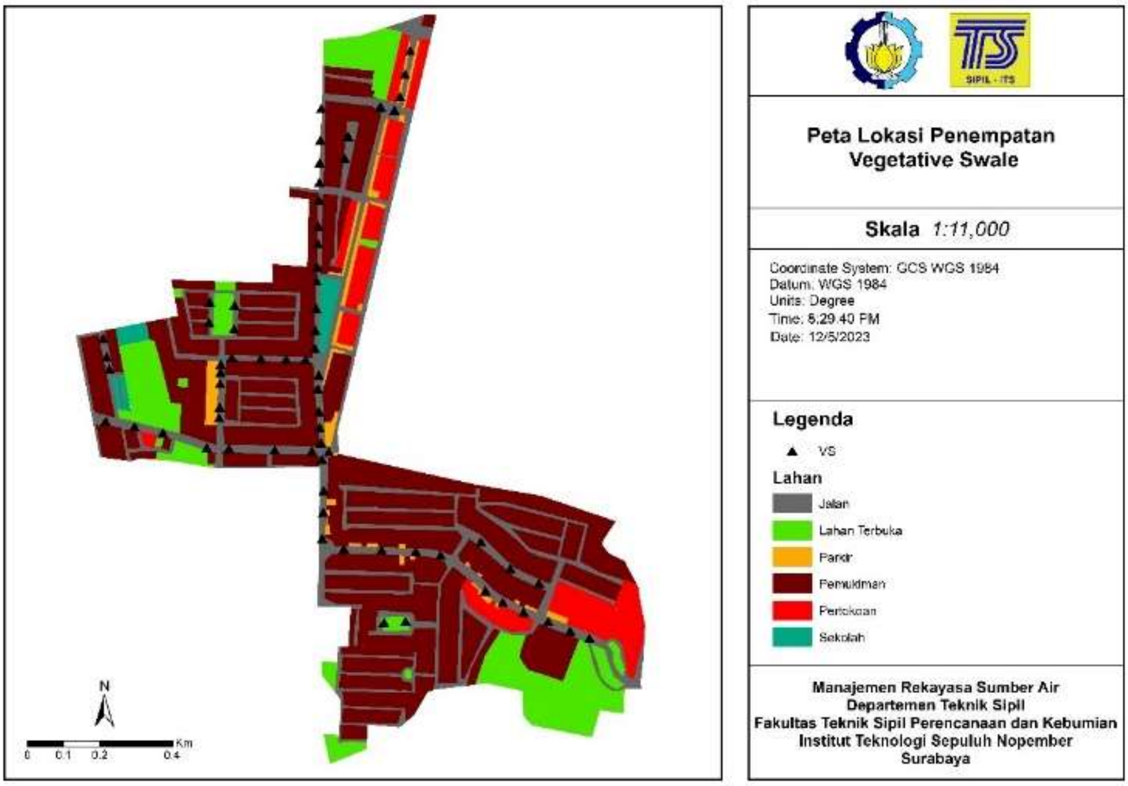


Source : Analysis result

Figure 6. Detail location of LID Porous Pavement



Source : Analysis result

Figure 7. Detail location of LID Vegetative Swale

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4. Results and Discussions

There are 4 simulation results, they are simulation without LID, scenario 1, scenario 2, and scenario 3. The following is a description of the results of each simulation:

4.1 Simulation Without LID

Based on the statistical results of the SWMM modeling report, it was found that the highest surface runoff value occurred in sub-catchment 37 with a total surface runoff of 9.13 x 10^6 ltr with peak discharge occuring was 0.97 m3/sec. Overall simulation results are as in Table 4.

Table 4. Summary result of surface runoff simulation without LID

Information	Volume (hectare-m)
Total Precipitation	9,531
Infiltration Loss	2,155
Surface Runoff	6,574

Source: Simulation result

4.2 Scenario 1

Scenario 1 uses LID PP (Porous Pavement). Based on the statistical results of the SWMM modeling report, it was found that the highest surface runoff reduction value occurred in subcatchment 28 with a total surface runoff of 4.18 x 10^6 ltr. Overall simulation results are in Table 5.

Table 5. Summary result of surface runoff simulation scenario 1

Information	Volume (hectare-m)
Total Precipitation	9,531
Infiltration Loss	2,208
Surface Runoff	6,189

Source: Simulation result

4.3 Scenario 2

Scenario 2 uses LID VS (Vegetative Swale). Based on the statistical results of the SWMM modeling report, it was found that the highest surface runoff reduction value occurred in sub-catchment 37 with a total surface runoff of 8,90 x 10^6 ltr. Overall simulation results are in Table 6.

Table 6. Summary result of surface runoff simulation scenario 2

Information	Volume (hectare-m)
Total Precipitation	9,531
Infiltration Loss	2,232
Surface Runoff	6,476

Source: Simulation result

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4.3 Scenario 3

Scenario 3 uses a LID combination of 50% PP (Porous Pavement) and 50% VS (Vegetative Swale). Based on the statistical results of the SWMM modeling report, it was found that the highest surface runoff reduction value occurred in sub-catchment 28 with a total surface runoff of 4,410 x 10^6 ltr. The overall simulation results are in Table 7.

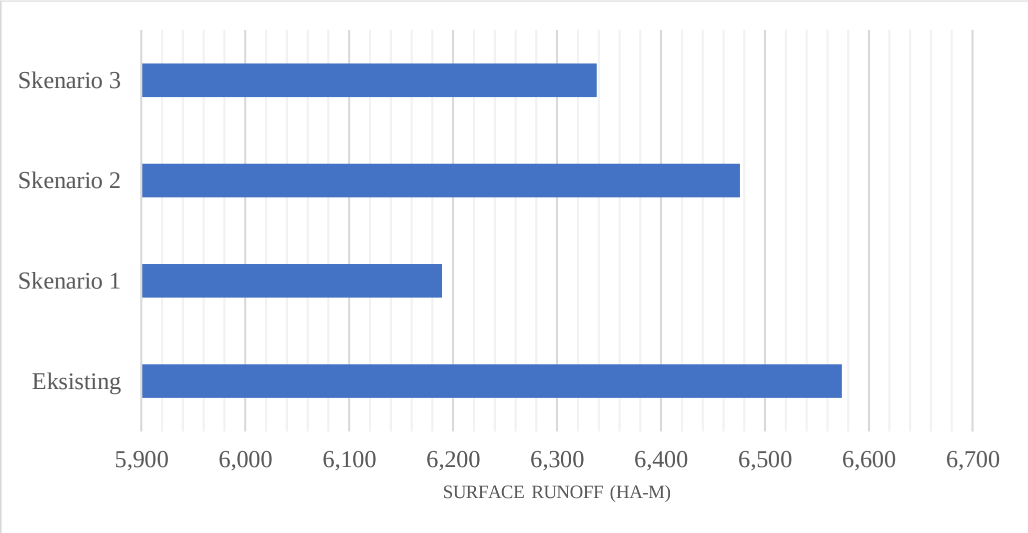
Table 7. Summary result of surface runoff simulation scenario 3

Information	Volume (hectare-m)
Total Precipitation	9,531
Infiltration Loss	2,216
Surface Runoff	6,338

Source: Simulation result

4.4 Comparison Results

To see how effective LID control is from the 3 scenarios above and the suitability of the installed LID control, a comparison of the results from each simulation was carried out as in Figure 8 and Table 7.



Source : Analysis result

Figure 8. Comparison surface runoff volume

Table 8. Comparison Installed area LID

Scenario type	LID	Installed Area (ha)	Installed Percentage
Scenario 1	Porous Pavement	2,69	2,81 %
Scenario 2	Vegetative Swale	1,91	2,00 %
Scenario 3	50% Porous Pavement + 50% Vegetative Swale	2,30	2,40 %

Source: Analysis result

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5. Conclusion and Suggestion

5.1 Conclusions

1. 3 Low Impact Development scenario models can be applied to the location, scenario 1 LID Porous Pavement with LID installed percentage 2,81%. Scenario 2 LID Vegetative Swale with LID installed percentage of 2,00%. Scenario 3 LID 50% Porous Pavement and 50% Vegetative Swale with LID installed percentage of 2,40%. Scenario 1 has the highest percentage value, which means the level of suitability with land use in the location is high.
2. 3 Low Impact Development scenario models have an effect on surface runoff discharge, scenario 1 with LID porous pavement with a total reduction in surface runoff of 0,385 ha-m. Scenario 2 with vegetative swale LID with a total reduction in surface runoff of 0,098 ha-m. Scenario 3 with LID 50% porous pavement and 50% vegetative swale with a total reduction in surface runoff of 0,236 ha-m. Scenario 1 has the highest impact on reducing surface runoff, which means that the effectiveness of LID at locations is high.

5.2 Suggestion

Further research can focus on maximizing the performance of LID with a combination of LID other than the above to achieve effective performance for reducing surface runoff in this area.

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