Civil and Environmental Science Journal
Vol. 6 No. 2 (2023)

Civil and Environmental Science Journal (CIVENSE)

Journal homepage: https://civense.ub.ac.id/index.php/civense/index

Original research article

Analysis of Made Lamongan Residential Drainage System Using SWMM (Storm Water Management Model) and HEC-RAS (Hydraulic Engineering Centre-River Analysis System) Models

Ridwan Febrianto *, Mohammad Bisri, Evi Nur Cahya

Department of Water Resources Engineering, Brawijaya University, 65145, Indonesia

ARTICLE INFO

Keywords:
Precipitation;
Surface runoff;
Design discharge;
SWMM;
HEC-RAS

ABSTRACT

Made Lamongan Residential is located in an area that has a flat slope and is flanked by two rivers Kali Mengkuli and Kali Gorok, the problem in the study area is that the drainage system is unable to serve rainwater runoff. This is evidenced by the occurrence of inundation during the rainy season with high intensity. The height of the inundation that occurs in the Residential complex ± 60 cm with a reduction in inundation of more than 12 hours. The calculation results showed that there were several sections of the channel that occurred runoff with a planned Q5 flood discharge of 8.14 m^3/sec. Based on the results of surveys in the field, many channels were found that had changed their dimensions due to the renovation of residents' houses. In this study, 1D channel hydraulic modelling was carried out using SWMM and HEC-RAS software to obtain a model that was close to the surface runoff conditions at the study site. The purpose of this study is to obtain the greatest handling of inundation in Made Residential in reducing the height of the inundation based on the model to be carried out, as well as obtaining the value of model calibration at the study site.

1. Introduction

At the study site, the capacity of the drainage system appears to be inadequate for the densely populated land, and many channels are narrowed due to residents permanently closing the drainage in front of their houses. The imagery shows limited green open space, thus requiring an evaluation of the drainage capacity and model confirmation while considering the occurring floods [1]. Previous studies, such as Henny Rica Yunita, and Dani Eko, are used as references in this study to find appropriate solutions for drainage issues [2]–[4].

At the study location, the drainage system still relies on gravity to be discharged through one channel, the Gorok river (irrigation drainage), which flows into the Tanjung river and then empties into the Bengawan Solo river. Due to the high water discharge in the Gorok river, the drainage system in Made Housing often experiences water congestion, causing floods on the roads. Additionally, many drainage channels in Made Housing do not have the same dimensions due to the influence of irregular house fence construction, closing off some of the channels and making it difficult for rainwater to enter.

In this study, SWMM and Hec-Ras were chosen for modeling because both software can represent modeling in one dimension [5]–[6]. This research is based on:

- To find out whether the existing drainage system and technology are still feasible.
- To find out the channel capacity and flow direction whether it is appropriate in tackling existing runoff.
- To find out the right alternative technology in tackling floods in Made residential.

2. Method

The study location is in Made residential, Made Village, Lamongan District, Lamongan Regency, with a residential area of ± 54.28 ha. The geographical location of the Lamongan District is in the position of 112° 23' 22.80" East Longitude and 7° 7' 30.69" South Latitude. The location map can be seen in **Figure 1**.

2.1. *Tools and Materials*

In this study there are several tools and materials used, the tools used are free helper software that can be downloaded freely while materials are obtained from consultant planning

*Corresponding author: Department of Water Resources Engineering, Brawijaya University, 65145, **Indonesia**
E-mail address: febri.r1d@gmail.com (Ridwan Febrianto)
doi: 10.21776/civense.v6i2.396
Received: 27 December 2022; Revised: 26 October 2023 Accepted: 29 October 2023
E-ISSN: 2620-6218

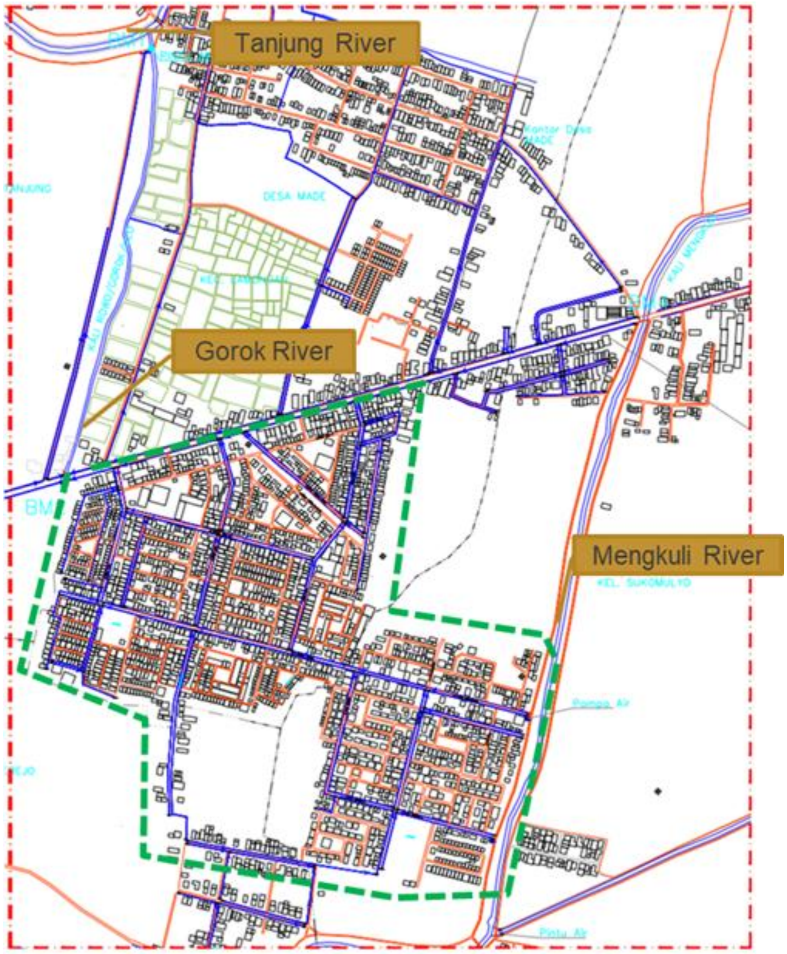

Figure 1. Percut Watershed

work. The study requires several tools, including Google Earth Pro 7.3.6.9326, EPA SWMM 5.2, HEC-RAS 6.2, and Microsoft Office Home 2016. Additionally, the materials used include RTRW Map 2020-2025, rainfall data from 2012 to 2021, topographic maps at a scale of 1:2000 for residential areas, channel cross-section data, and surface runoff observation data [2]–[18].

2.2. *Methods*

This study was conducted in the Made residential area, the steps of this study were arranged systematically so as to facilitate its completion. Data collection in this study comprises primary and secondary data. The primary data includes conducting a survey to identify inundation areas and their causes, as well as an inventory survey of existing drainage conditions, such as channel width, height, shape, length, slope, and water flow direction. On the other hand, the secondary data needed are maps related to the study area's condition, supporting data such as rainfall and existing drainage networks, and supporting documents like RTRW and Master Plan. Rain data from the nearest station with a minimum of 10 years of data are collected as much as possible [1]–[4], [6], [7], [9]–[15], [17]–[24].

2.3. *Data Analysis*

After collecting data, the 10-year rain data was selected for the maximum annual daily rain value and then the consistency test was carried out using the RAPS method, if the test results were good, the rain data would later be used for design rain analysis. Design rain analysis was performed using Log Pearson Type III. The results of the analysis will be tested for frequency distribution using the Smirnov Kolmogorov and Chi Square methods to obtain the correctness of the hypothesis from the calculated method and then choose which method is the most suitable for the design of rain design to take [1], [7].

2.4. *Hydrological Analysis*

A unit hydrograph is defined as a direct runoff hydrograph caused by effective rainfall with a uniform intensity of falling evenly throughout the DTA for a certain duration. The volume of runoff will be estimated using the SCS (Soil Conservation Service) method. In using the SCS method, the volume of runoff from a DTA that falls rainwater is determined based on the characteristics of its sub DTA, which is measured from a map or assessment at the time of field observation, the parameters of the sub DTA concerned are the area, length and slope of the flow site, as well as land use. Land use parameters include impermeable and permeable components as well as types of pervasive components. Among the most decisive sub DTA parameters for runoff volume are the percentage of impermeable area and Curve Number (CN). A higher CN means that the volume of runoff is also higher, with a theoretical limitation of CN = 85 which means it is equal to its runoff volume of 85%. The SCS method obtains the output of the design flood discharge which will be used as input in the next analysis [1], [3], [7], [12], [21], [25], [26].

2.5. *Hydraulic Analysis*

The results of the flood hydrograph design of the SCS method were then carried out 1D hydraulic modeling using two software: EPA-SWMM and HEC-RAS. The results of the modeling will later be viewed the flow profile on each channel section and will be compared with the results of the inundation height survey on the channel section at the study site [5], [6], [17], [25].

2.6. *Calibration and Validation*

To test the accuracy of the model, the results of hydraulic analysis in two software: EPA-SWMM and HEC-RAS in the form of a flow profile model, then looked at the water runoff height above the channel and took the average runoff height for each channel segment. The high runoff value of the two models will later be seen as correlated with the results of a high runoff survey on each channel section obtained at the time of the flood. As for calibration in the selected model, the channel manning value input will be carried out and correlations tested again to get an accurate value according to flood event conditions [5], [6], [17].

3. Result and Discussion

3.1. *Rainfall Data Analysis*

The maximum rainfall amount of the area was obtained using data from daily rainfall stations, in this study the location of the rain station was outside the catchment area of the study location, Lamongan Station for the period of observation of rainfall data used for 10 (ten) years from 2012 to 2021. Outlier examination is an examination of data that deviates quite far from the trend of the group. The existence of an outlier usually greatly interferes with the selection of the type of distribution of a sample of data, so this outlier data needs to be discarded. Before this rain data is used, it must first pass testing for the consistency of the data. The method used is the RAPS (Rescaled Adjusted Partial Sums) method. If Q/(n0.5) calculate < from Q/(n0,5) plan then the data tested is feasible to use, From the calculation in **Table 1**, Q/(n0.5) count = 0.740 < 1.290 then the consistency test is accepted, If R/(n0.5) calculate < from R/(n0,5) plan then the data tested is suitable for use, From the calculation in **Table 1**, obtained R/(n0,5) Calculate = 1.124 < 1.380 then the consistency test is accepted.

Furthermore, the calculation of rainfall design uses the Log Person Type III Method with retries of 2, 5, 10, 20, and 25. The calculations can be seen in **Table 2**. From the calculation of the distribution test, the smallest max D price was obtained, namely by using the Log Pearson III distribution with a value of 0.091. So that for subsequent calculations used the results of the distribution of Log Pearson III. To calculate the rainfall plan in the study area selected results from the Log Pearson Type III, the calculation of the magnitude of rain intensity can be used with several empirical formulas in hydrology, the Mononobe Formula is used if short-term rain data is not available, there is only daily rain data, Flood discharge design selected based on Pu Regulation No. 12 year 2014 with a DTA category of 10-100 ha The typology of the city is medium then selected flood discharge design 5 year (**Table 3**) [1].

Table 1. Rain Data Consistency Test (RAPS) of Lamongan Rain Station

No	Year	Rain (mm/day)	Sk*	D_y^2	Sk**	[Sk**]
1	2012	77.0	-7.70	6.59	-0.326	0.326
2	2013	72.0	-12.70	17.92	-0.538	0.538
3	2014	83.0	-1.70	0.32	-0.072	0.072
4	2015	59.0	-25.70	73.39	-1.088	1.088
5	2016	92.0	7.30	5.92	0.309	0.309
6	2017	56.0	-28.70	91.52	-1.215	1.215
7	2018	92.0	7.30	5.92	0.309	0.309
8	2019	96.0	11.30	14.19	0.478	0.478
9	2020	140.0	55.30	339.79	2.341	2.341
10	2021	80.0	-4.70	2.45	-0.199	0.199
Total	847.00		558.01			
Average	84.70					

Table 2. Rain Design Calculation Results

Percent	Tr	G	G . SD	R_{Design}
50	2	-0.081	-0.009	80.328
20	5	0.807	0.092	101.300
10	10	1.320	0.150	115.793
20	20	1.706	0.193	128.075
25	25	1.899	0.215	134.696

Table 3. 6-Hour Rain Distribution On 5-Year Rain Design

Hour	Ratio %	C.H.netto hour period
1	55.032	55.748
2	14.304	14.490
3	10.034	10.164
4	7.988	8.092
5	6.746	6.833
6	5.896	5.973

3.2. *Rainwater Discharge Calculation with SCS SWMM Method*

In the calculation of flood discharge design with the SCS SWMM model, it is first carried out to input image maps from Google that have been registered in UTM so that when tracing DTA limits can be directly calculated area and length of the channel, for input CN values at the study site, CN 85 values are taken based on the old resident classification with a population density of >350 people/ha (Figure 2). Then, Figure 3 show the SWMM software running software runoff discharge chart.

3.3. *Channel Capacity Analysis with HEC-RAS Auxiliary Program*

The calculation of secondary and primary channels will be carried out with the HEC-RAS auxiliary program, the first step in the HEC-RAS simulation is to create a channel scheme, then the cross-sectional input of the channel, the discharge input used is the debit calculation of the SCS SWMM method as shown in Figure 4 and Recapitulation of Surface Runoff Height of HEC-RAS Model shown in Table 4.

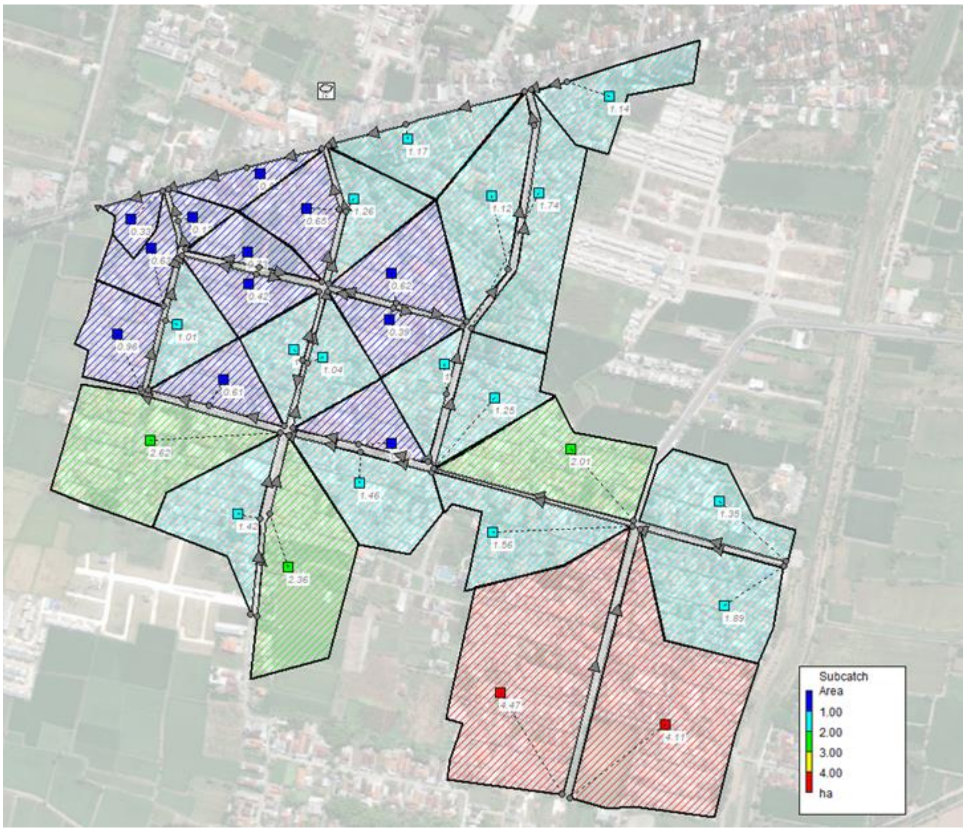

Figure 2. Catchment Area Division Map and Flow Direction in SWMM Software

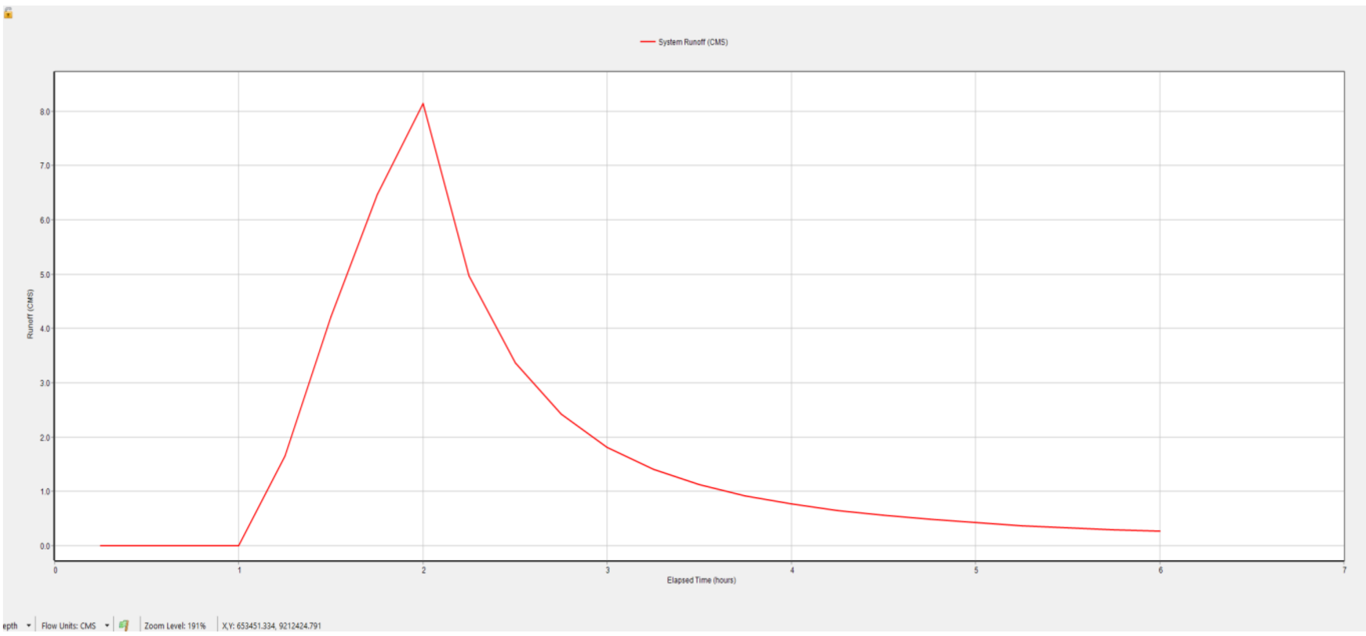

Figure 3. SWMM Software Running Software Runoff Discharge Chart

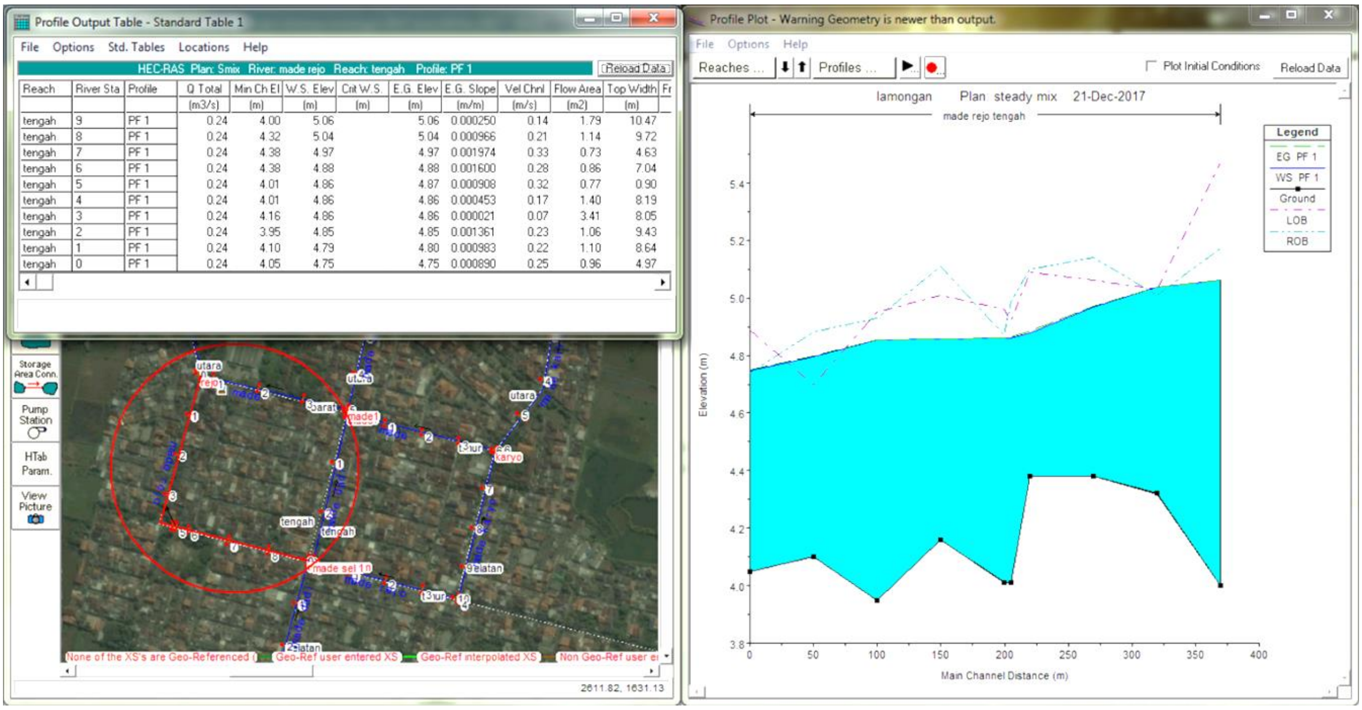

Figure 4. One example of the results of the long section of the existing channel sta 0-350 Jl. Made Rejo

Table 4. Recapitulation of Surface Runoff Height of HEC-RAS Model

No	Street Names	Runoff (m)
1	Mastrip	0
2	Made Rejo	0.1
3	Made Dadi	0.2
4	Made Mulyo	0.4
5	Made Kidul	0.3
6	Made Karyo	0.3
7	Ikan Bandeng	0.1
8	Ikan Lele	0.6

3.4. *Channel Capacity Analysis with SWMM Auxiliary Program*

This calculation is carried out to determine whether the existing condition of the channel is able to accommodate and drain the design flood discharge or not (Figure 5). From the results of the calculation of the capacity of the existing channel, it can be concluded that the dimensions of the existing channel are not able to accommodate and drain the design flood discharge so that it is necessary to re-plan the dimensions of the drainage channel, so that there is no flooding or inundation due to overflowing water levels from the channel (Figure 6). From the existing dimensions that have been inputted into the SWMM auxiliary program, it is then run along with the calculation of discharge and channel capacity can be seen in Table 5, so that as many as 36 over capacity segments and 23 safe segments are obtained.

3.5. *Test the Suitability of the Model with Existing Inundation Conditions*

The criterion used to measure the goodness of a model after a model is obtained is root mean square error (RMSE). RMSE is a model selection tool based on error estimation results. The existing error indicates how much the estimated result differs from the value to be estimated.

From the Table 6, the RMSE value from the HEC-RAS and SWMM models is obtained which is compared with the results of observations/information on the height of the wedge in the field by the community and PU Lamongan, from the RMSE results of each road section if the average that has the smallest value is the SWMM model, so for subsequent calculations using the results from SWMM.

3.6. *Calibration Of Selected Models*

From the results of the RMSE calculation, a selected model has been obtained, namely the SWMM model, then from the results of the initial analysis that has been modeled, then the SWMM model calibration is carried out. Calibration was carried out by adjusting the channel manning value which in the previous model input the manning value was 0.025, from several experiments obtained a manning value of 0.011, which was subsequently used for channel repair analysis. The results of the RMSE test on both manning values can be seen in Table 7.

3.7. *Drainage Channel Repair Analysis*

In this study, the improvement of drainage channels was carried out in 2 ways, namely by increasing the depth of the existing drainage channel / changing dimensions and changing the drainage system by dividing it into 2 systems, with this improvement it is hoped that the discharge that overflows can be reduced or even until there is no runoff.

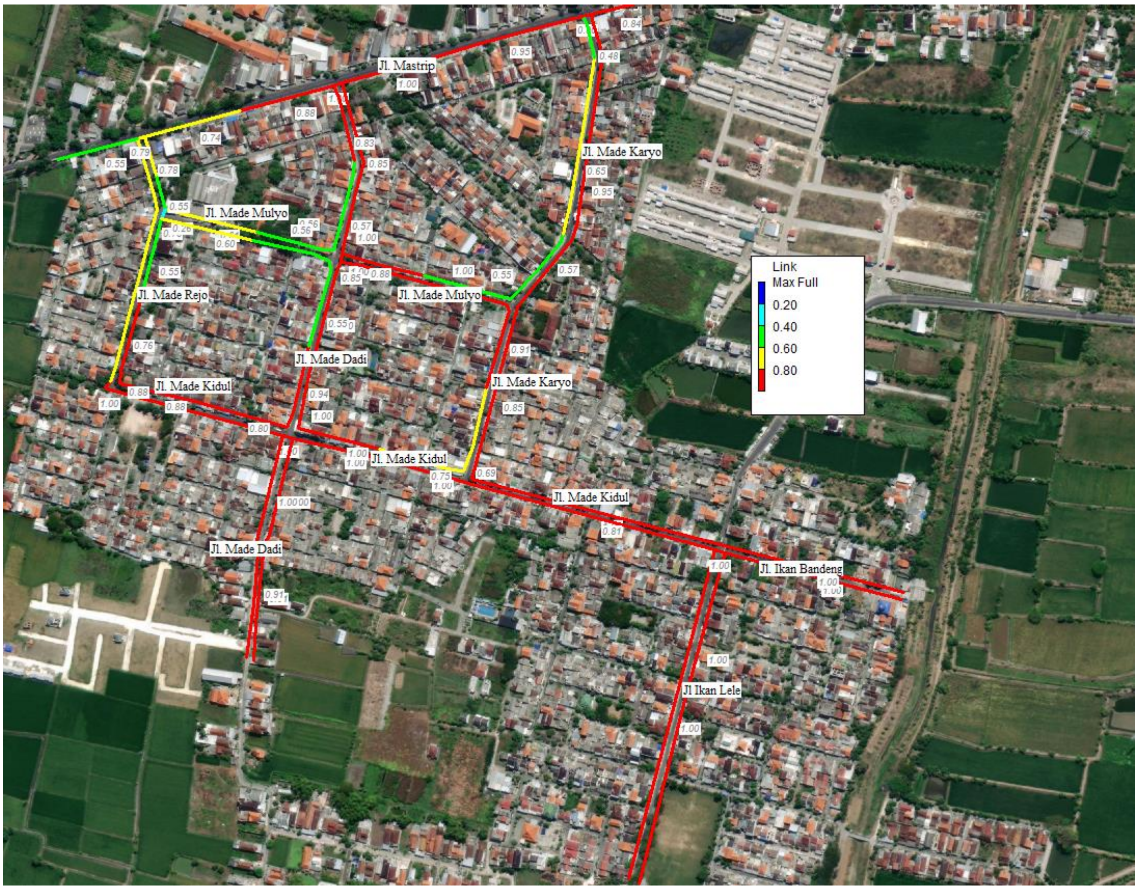

Figure 5. High Distribution Map of Inundation Results of Running Software SWMM

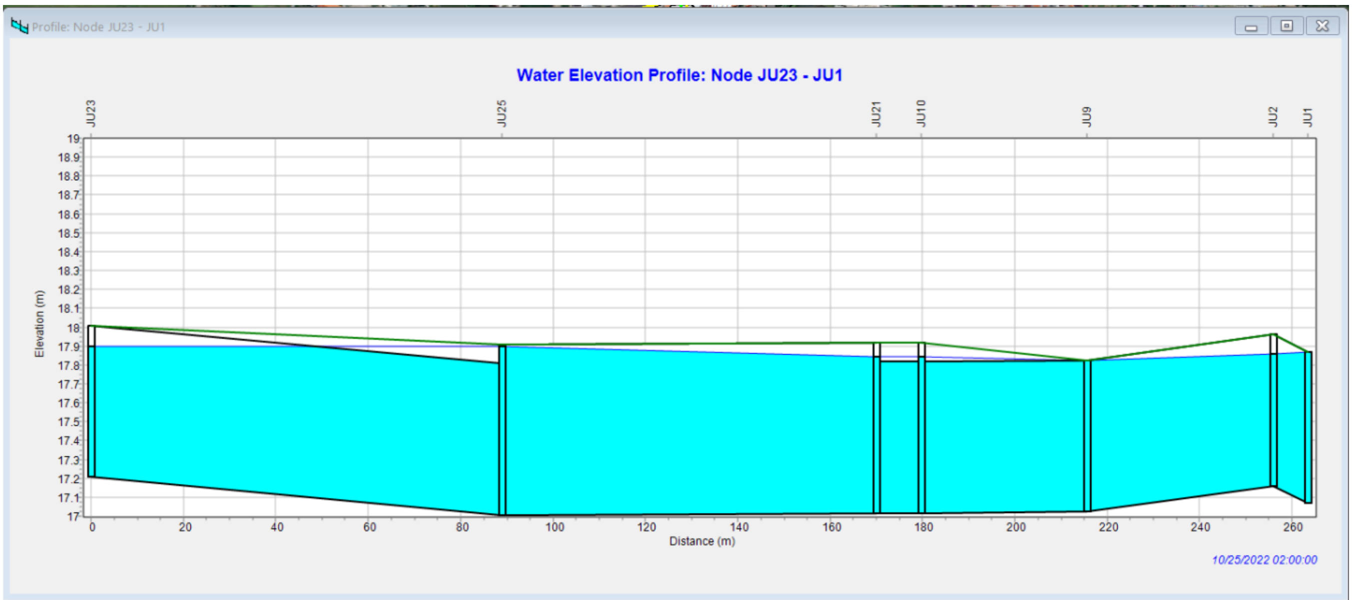

Figure 6. One Example of The Results of The Ju1-Ju23 Elongated Cut Section Jl. Made Rejo

Table 5. Recapitulation of Surface Runoff Height of HEC-RAS Model

No	Street Names	Runoff (m)
1	Mastrip	0.2
2	Made Rejo	0.4
3	Made Dadi	0.5
4	Made Mulyo	0.5
5	Made Kidul	0.2
6	Made Karyo	0.4
7	Ikan Bandeng	0.4
8	Ikan Lele	0.5

Table 6. RMSE Testing on Both Models

No	Street Names	Runoff Height Observation (m)	HEC-RAS Runoff (m)	SWMM Runoff (m)	HEC-RAS RMSE	SWMM RMSE
1	Mastrip	0.3	0	0.2	0.09	0.03
2	Made Rejo	0.4	0.1	0.4	0.09	0.00
3	Made Dadi	0.5	0.2	0.5	0.09	0.00
4	Made Mulyo	0.4	0.4	0.5	0.00	0.03
5	Made Kidul	0.6	0.3	0.6	0.09	0.00
6	Made Karyo	0.6	0.3	0.4	0.09	0.06
7	Ikan Bandeng	0.5	0.1	0.4	0.12	0.03
8	Ikan Lele	0.6	0.6	0.6	0.00	0.00
			Average RMSE		0.07	0.02

Table 7. RMSE Testing on Both Models

No	Street Names	Runoff Height Observation (m)	SWMM Model Runoff (m)	SWMM Calibration Runoff (m)	SWMM Model RMSE	SWMM Calibration RMSE
1	Mastrip	0.3	0.2	0.3	0.03	0.00
2	Made Rejo	0.4	0.4	0.4	0.00	0.00
3	Made Dadi	0.5	0.5	0.5	0.00	0.00
4	Made Mulyo	0.4	0.5	0.5	0.03	0.03
5	Made Kidul	0.6	0.6	0.6	0.00	0.00
6	Made Karyo	0.6	0.4	0.5	0.06	0.03
7	Ikan Bandeng	0.5	0.4	0.4	0.03	0.03
8	Ikan Lele	0.6	0.6	0.6	0.00	0.00
			Average RMSE		0.02	0.01

From the two system analyses, it will be modeled again in the SWMM auxiliary program which will later be selected which system analysis can reduce channel segments that overflow more than 50% of the existing running results with 36 segments overflowing.

3.7.1. *Analysis of Drainage Canals Repair Without Polder System*

The channel will be planned using U-Ditch precast concrete (Table 8), At the study site due to limited land, it is not possible to increase the width of the channel and cannot change the depth of the channel that is too large, so only a few sections of the road have been changed dimensions, from these results although it reduces the height of the channel water runoff but there are still as many as 29 channels that overflow. The results of the modeling can be seen in Figure 7.

3.7.2. *Analysis of Drainage Channel Repair with Polder System*

In the 2nd simulation, namely by changing the drainage system to a north and south system, by adding a door in Figure 8, for the northern system, it only changes the dimensions of the drainage channel in the main collector (primary) and still flows gravitationally into the Gorok river, while for the southern system by adding a retention pond and the pump is then discharged into the Mengkuli river, obtained a channel that crosses 15 segments with an average runoff height of 10-20 cm only.

For the southern system (Figure 9), a spool will be added with an area available at the site is 250 m^2 with a plan pool depth of 2.5 m so that a pool capacity of 625 m^3 is obtained while the pump specification plan for the southern system (Table 9).

Table 8. New Channel Dimensioning With U-Ditch Analysis Without Polder System

No	Channel Code	Street Names	Wide (m)	Channel Height (m)
1	SAL4	Made Rejo	1.2	1
2	SAL5	Made Rejo	1.2	1
3	SAL8	Made Rejo	1.2	1
4	SAL10	Mastrip	1.4	1.4
5	SAL11	Mastrip	1.4	1.4
6	SAL12	Mastrip	1.4	1.4
7	SAL13	Mastrip	1.4	1.4
8	SAL19	Made Rejo	1.2	1
9	SAL30	Made Dadi	0.5	1
10	SAL31	Made Dadi	0.5	1
11	SAL32	Made Dadi	0.8	1
12	SAL34	Made Kidul	0.5	0.6
13	SAL42	Made Karyo	0.8	1
14	SAL47	Mastrip	1.4	1.4
15	SAL51	Made Dadi	0.8	0.6
16	SAL14	Mastrip	1.4	1.4
17	SAL54	Mastrip	1.4	1.4
18	SAL55	Ikan Lele	0.6	0.5
19	SAL56	Ikan Lele	0.6	0.8
20	SAL57	Ikan Bandeng	1	1
21	SAL58	Ikan Bandeng	1	1
22	SAL60	Made Kidul	0.8	1
23	SAL61	Made Karyo	0.8	1
24	SAL62	Ikan Bandeng	1	1

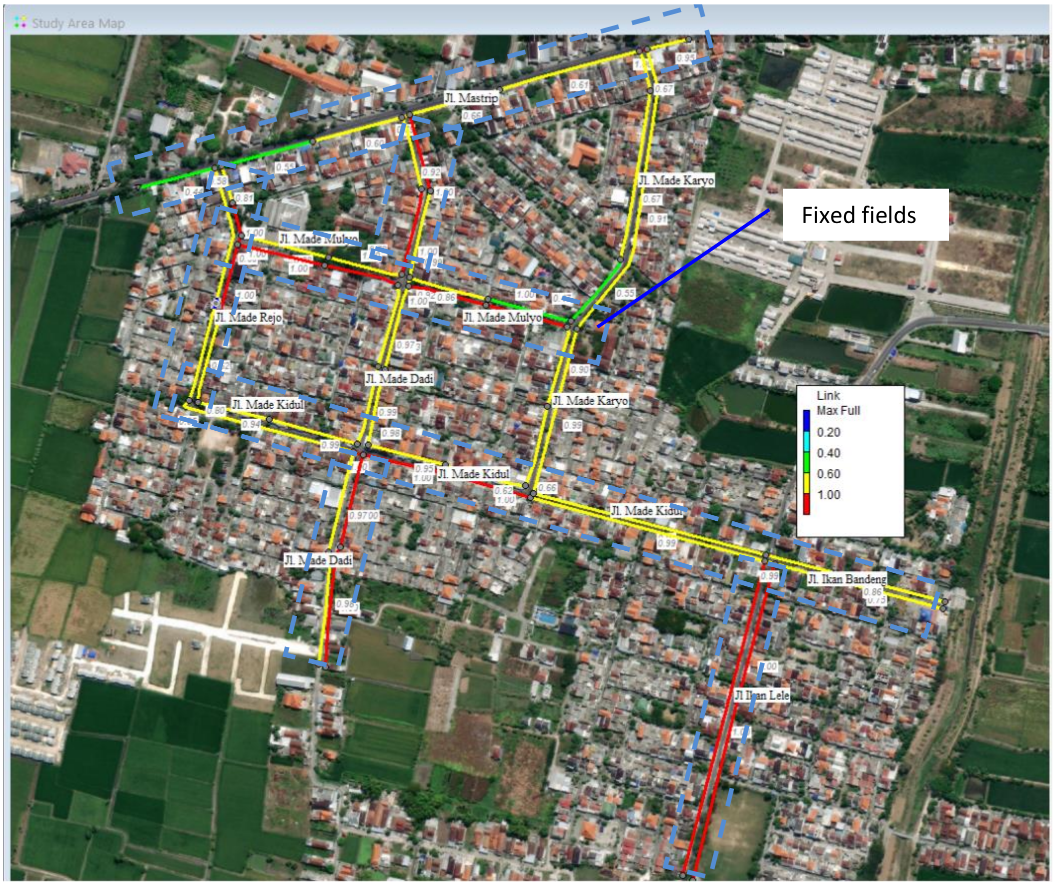

Figure 7. High Distribution Map of Inundation Results of Running Software SWMM Without Polder System

Table 9. Pump specification

Number of Pumps	:	2 (two) flood pumps capacity 0.25 m3 / second
Pump Type	:	Sewage Pump
Capacity	:	0.5 m3/s

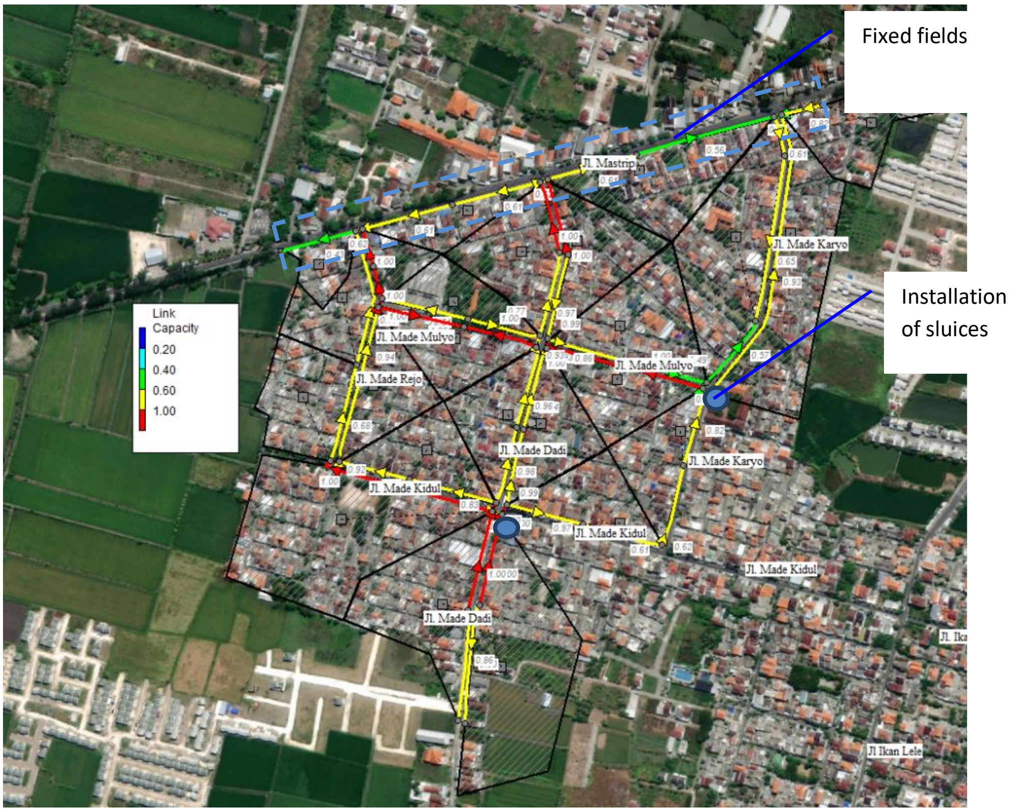

Figure 8. North System Inundation High Spread Map with Polder System

Figure 9. South System Inundation High Spread Map with Polder System

4. Conclusion

The evaluation study of the existing drainage capacity assisted by pump operation in the retention pond against the Q5 flood design discharge concluded that the analysis of the existing drainage system using the HEC-RAS and SWMM models resulted in an average runoff depth of 0.25 m and 0.45 m on all sections, respectively. Based on the RMSE testing results, the SWMM model was the most suitable for the flood condition at the study location. The recommended drainage system improvement at the study location according to the SWMM model is a polder system, as it can divide the flow direction into two collectors and reduce the accumulation of the main channel load on JL. Mastrip before discharging to the river. In the existing condition, there are 36 flowing channels with an average flooding depth of 0.55 and a duration of 3-6 hours based on the survey. However, the model results for the polder system indicate that the flowing channels were reduced to 15 with an average flooding depth of 0.12 and a duration of 1-2 hours.

Author Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

Funding

No funding information from the authors.

Availability of data and materials

All data are available from the authors.

Competing interests

The authors declare no competing interest.

Additional information

No additional information from the authors.

References

[1] H. Saidah *dkk.*, "Drainase Perkotaan," *Yayasan Kita Menulis*, 2021.

[2] H. Sudjatmiko, M. Bisri, dan E. Yuliani, "Studi Evaluasi & Perbaikan Sistem Drainase di Polder Jati Pinggir Kanal Banjir Barat DKI Jakarta," *Jurnal Teknik Pengairan: Journal of Water Resources Engineering*, vol. 7, no. 2, pp. 205–215, 2016.

[3] A. Yunianta, Suripin, dan B. H. Setiadji, "Application of sustainable road drainage system: Simulation by using SWMM program," *Civil Engineering and Architecture*, vol. 8, no. 2, pp. 55–65, 2020.

[4] M. D. Fahma, E. Noerhayati, dan A. Rokhmawati, "Studi Evaluasi Saluran Drainase Stadion 17 Mei Banjarmasin Provinsi Kalimantan Selatan Menggunakan EPA SWMM 5.1," *Jurnal Rekayasa Sipil (e-journal)*, vol. 13, no. 1, pp. 238–246, 2023.

[5] M. H. Alfian dan E. Kurniyaningrum, "Analisis Pengendalian Banjir pada Das Sungai Kabur-Kabur di Wilayah Kota Bula dengan Pemodelan HEC-RAS dan EPA SWMM.," *Journal of Syntax Literate*, vol. 8, no. 7, 2023.

[6] S. Fauziah, S. I. Wahyudi, dan H. Poedjiastoeti, "Analisis Saluran Drainase di Pusat Kota Jepara dengan Program EPA SWMM 5.1 dan HEC RAS 4.1. 0," *Bentang: Jurnal Teoritis dan Terapan Bidang Rekayasa Sipil*, vol. 10, no. 2, pp. 97–108, 2022.

[7] M. B. Al Amin, *Pemodelan Sistem Drainase Perkotaan Menggunakan SWMM*. Deepublish, 2020.

[8] I. Ibrahim, A. Irwansyah, dan S. K. Intan, "Aplikasi software swmm untuk studi permasalahan banjir pada kawasan politeknik negeri lhokseumawe," *Portal: Jurnal Teknik Sipil*, vol. 10, no. 1, 2018.

[9] D. S. Bisht, C. Chatterjee, S. Kalakoti, P. Upadhyay, M. Sahoo, dan A. Panda, "Modeling urban floods and drainage using SWMM and MIKE URBAN: a case study," *Natural Hazards*, vol. 84, no. 2, pp. 749–776, Nov 2016.

[10] A. Husaini, F. Fasdarsyah, M. Fahmi, R. Mirsa, dan A. Jalil, "Analisis Kapasitas Saluran Drainase Terhadap Debit Maksimum Di Kota Lhokseumawe Dengan Menggunakan Software SWMM 5.1," *Malikussaleh Journal of Mechanical Science and Technology*, vol. 6, no. 2, pp. 24–27, 2022.

[11] M. Fuat, "Studi Evaluasi Drainase Perkotaan Kecamatan Patrang Menggunakan SWMM (Studi Kasus Jalan Merpati dan Jalan Nusa Indah)" *Undergraduate Thesis*, Universitas Jember, 205.

[12] T. G. Schmitt, M. Thomas, dan N. Ettrich, "Analysis and modeling of flooding in urban drainage systems," *J Hydrol (Amst)*, vol. 299, no. 3–4, pp. 300–311, Des 2004.

[13] . J. dan M. Gasali M., "Evaluasi Perencanaan Drainase Menggunakan Simulasi HEC RAS 4.0 (Studi Kasus : Jalan Budiman – Tembilahan)," *Selodang Mayang: Jurnal Ilmiah Badan Perencanaan Pembangunan Daerah Kabupaten Indragiri Hilir*, vol. 7, no. 1, pp. 30–39, Apr 2021.

[14] Y. Indriani, "Studi Evaluasi Sistem Saluran Drainase di Kecamatan Kapas, Kabupaten Bojonegoro, Provinsi Jawa Timur," *Jurnal Teknik Pengairan*, vol. 13, no. 2, pp. 172–182, Nov 2022.

[15] R. Faizal, N. A. Prasetya, Z. Alstony, dan A. Rahman, "Evaluasi Sistem Drainase Menggunakan Storm Water Management Model (SWMM) dalam Mencegah Genangan Air di Kota Tarakan," *Borneo Engineering: Jurnal Teknik Sipil*, vol. 3, no. 2, pp. 143–154, 2019.

[16] N. Nofrizal dan J. T. Agusman, "Simulasi Genangan Air Dengan Menggunakan Software HEC-RAS (Studi Ruas Jalan Ampang Pulai, Kecamatan Koto XI Tarusan, Pesisir Selatan)," *Ensiklopedia of Journal*, vol. 5, no. 1, pp. 270–277, 2022.

[17] E. Efrizal, Y. A. Saputro, dan N. Hidayati, "Implementasi Software Hec-Ras 4.1. 0 Dan Epa Storm Water Management Model (Swmm) 5.1. 0 Pada Efektivitas Analisis Saluran Drainase (Studi Kasus Desa Kelet Kecamatan Keling Kabupaten Jepara)," *Jurnal Civil Engineering Study*, vol. 2, no. 01, pp. 7–16, 2022.

[18] M. P. Secilia, M. Bisri, dan U. Andawayanti, "Studi Evaluasi Sistem Drainase Air Limpasan Permukaan Di Site Gurimbang Mine Operation PT Berau Coal," *Jurnal Teknologi dan Rekayasa Sumber Daya Air*, vol. 3, no. 2, pp. 719–732, 2023.

[19] R. J. Betaubun dan D. Hari Suseno, "Analisis Penanggulangan Genangan di Kota Ambon Pada Das Waitomu Kelurahan Uritetu." *Undergraduate Thesis*, Universitas Pattimura, 2013.

[20] G. Di, K. P. Sekaki, D. Astuti, S. Dan, dan I. Suprayogi, "Analisis Kolam Retensi Sebagai Pengendalian Banjir," 2016. [Daring]. Tersedia pada: http://bappeda.pekanbaru.go.id/

[21] S. Andayani dan B. E. Yuwono, "Key Factors For Regional Urban Eco-Drainage Evaluation," *International Journal of Advances in Mechanical and Civil Engineering*, vol. 3, no. 1, pp. 1-6, 2016.

[22] E. Supriyani, M. Bisri, dan V. Dermawan, "Studi Pengembangan Sistem Drainase Perkotaan Berwawasan Lingkungan (Studi Kasus Sub Sistem Drainase Magersari Kota Mojokerto)," *Jurnal Teknik Pengairan: Journal of Water Resources Engineering*, vol. 3, no. 2, pp. 112–121, 2012.

[23] A. D. Handayanti, H. Syafarini, S. Darsono, dan S. Sugiyanto, "Perencanaan Sistem Drainase Wilayah Tawang Sari dan Tawang Mas Semarang Barat," *Jurnal Karya Teknik Sipil*, vol. 6, no. 2, pp. 194–203, 2017.

[24] A. Y. Muttaqin, "Kinerja Sistem Drainase Yang Berkelanjutan Berbasis Partisipasi Masyarakat (Studi Kasus di Perumahan Josroyo Indah Jaten Kabupaten Karanganyar)." *Thesis*, Universitas Diponegoro, 2006.

[25] G. A. Kandissounon, A. Kalra, dan S. Ahmad, "Integrating System Dynamics and Remote Sensing to Estimate Future Water Usage and Average Surface Runoff in Lagos, Nigeria," *Civil Engineering Journal*, vol. 4, no. 2, pp. 378, Mar 2018.

[26] F. R. Nomnafa, D. S. Krisnayanti, R. Ramang, dan I. M. Udiana, "Penggunaan Data Satelit TRMM terhadap Stasiun Curah Hujan di WS Noelmina," *Jurnal Teknik Pengairan*, vol. 13, no. 1, pp. 1–11, Jun 2022.