JICE Journal Innovation of Civil Engineering

Vol. 4, No. 2, pp. 185-194, 2023
Submit:16-11-2023 |
Accepted: 24-11-2023 |
Publish: 25-11-2023 |

RECHARGE WELLS MODEL BASED ON SHAPE FACTORS FOR FLOOD MANAGEMENT IN KLOJEN DISTRICT, MALANG CITY

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ABSTRACT
Urban flood areas hit various regions in Indonesia, such as what happened in Malang City. Flooding occurred in several areas of Klojen District, including Wilis Street, LetJen Suprapto Street in Samaan Village, Bareng Raya Street II in Bareng Village, Retawu Street, and Pulosari Street. This research uses a recharge well model based on shape factors to discuss flood mitigation. Data analysis includes existing floods, conditions of the study area, and an applied model adjusted to soil permeability in the research area. They were mapping the area (A) and coefficient C using ArcGIS 10.8 2023 software. The model applied is an infiltration well design constructed from a concrete buis at the top and soil pores at the bottom. The design rainfall calculation results are 592.112 mm/day. The results of the analysis show that there are a total of 30 channels from Samaan Village, Bareng Village, and Gading Kasri Village, whose channel capacity is unable, causing flooding. The geometric factor value of 3.14 m has a planned water inflow discharge of 1.7626 m3/second. Klojen sub-district requires 66 recharge wells to overcome the flooding. The application for constructing infiltration wells was carried out only in the Gading Kasri sub-district area, namely 11 infiltration wells. The infiltration well is planned to use a concrete buis with dimensions of 50x100 m, height L as deep as 2 m, bottom of porus in 1 m, and total depth of channel H is 3 m.

Keywords: *Recharge Wells; Shape Factors; Flood Management; Klojen Sub District.*

1. Introduction

Drainage is one of the facilities designed to meet the needs of the general public and is a main element in the infrastructure development of a city. Drainage is a means of channeling wastewater from residential areas and rainwater to avoid the risk of flooding due to increased water discharge in the channel. Currently, a problem that often arises in Malang City is drainage channels that are unable to accommodate overflowing water, causing puddles when it rains. This is due to the change in land use where what was originally a green area became a densely populated residential and industrial area, offices, and trade [1].

This problem occurs in Malang City, one of which is in Klojen District which has 11 sub-districts, Bareng, Gadingkasri, Kasin, Kauman, Kidul Dalem, Klojen, Oro-Oro Dowo, Penanggungan, Rampal Celaket, Samaan, Sukoharjo. Of these several sub-districts, there are 3 sub-districts that frequently experience flooding or standing water, Letjen Suprapto Street Gg I (Samaan Subdistrict), Bareng Raya II (Bareng Subdistrict), and JaGalunggung (Gading kasri Sub-district).

In the planning and development to improve the quality of the drainage network system, especially in Klojen District, Malang City, physical data is needed on drainage facilities and infrastructure from Malang City Government assets. There is a need to repair and maintain drainage channels as water channels to avoid the problem of drainage being clogged with rubbish, so careful planning is needed so that the drainage function runs optimally.

One effort to evaluate the drainage system is to use an infiltration well model based on geometric factors [2][3]. This method is used to measure the channel's capacity to accommodate runoff using a

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flat bottom infiltration well model using concrete buis construction at the top and pores at the bottom [4]. Analysis of existing data, flood area conditions, rain data, research area, and coefficient C using ArcGis 10.8 2023 [5]. The results of the analysis and models applied in the field are expected to be able to overcome flooding problems so that they are beneficial for society, namely creating a healthy environment, well-organized infrastructure and supporting the development of urban facilities in accordance with the spatial planning and regional planning of Malang City, especially in Klojen District.

2. Materials and methods

This research analyzes several locations in Klojen District that experienced flooding, Suprapto Gg I (Samaan Village), Jalan Bareng Raya II G (Bareng Village), and Galunggung Street (Gadingkasri Village). The following are the administrative boundaries for Samaan Village, Bareng Village, and Gading Kasri Village according to (BPS, 2021):

- Samaan Village: Area 5.39 ha, population 9,543 people
- Bareng Village: Area 10.65 ha, population 21,279 people
- Gading Kasri Village: Area 90,98 ha, population 14,175 people

2.1. Data collection

In the data collection stage, the data collected is primary data and secondary data.. it can as follows:

a) Topographic Map
b) Network and Drainage Channel Map
c) Rainfall Data
d) Land Use Map
e) Population Data

1. The primary data used is the soil permeability data which was obtained from the results of the in-situ permeability falling Head and was carried out independently by taking in a location in Gading Kasri Street, 6 samples of soil as a test material.
2. Secondary data is supporting data which needed as a reference for the analysis that was carried out such as rain intensity data in the Ciliwung, Sawojajar, and Sukun sub-districts for the last 10 years. It was obtained from the Public Works and Spatial Planning Office of Malang Regency, Network and Drainage Channel map, hydrology maps , land use maps, and several planning references in the book on sustainable urban drainage systems (Suripin), and calculation references Concerning the technical planning procedures for rainwater infiltration wells for yards.

2.2. Methodology

The stages of analysis carried out in the study are:

1. Average Rainfall

   The average rainfall data analyzed is in a certain period of time. Determination of the value of rainfall is taken according to the rain observation station (SPH) in the region. The rain observation stations taken according to (planning) have at least 3 comparison stations for data consistency and homogeneity. This method is used to calculate the average rainfall by taking into account the area of influence of each station [6].

   There are several ways to determine the average rainfall value in the region, there are 2 methods that can be used, namely [7]: Polygon Thiessen method, and Iso-hyet method. In accordance with regional conditions and the distribution of rain observation stations in Binangun sub-district, the Polygon Thiisen method of average rainfall is used. The formula for determining average rainfall is the Thiessen Polygon Method as follows[8]:

$$Ri = \frac{Ra\ x\ Aa + R\ \ x\ Ab + R\ \ x\ Ac}{Aa + Ab + Ac} \tag{1}$$

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Information :
Ri : Average rainfall
Ra : High average rainfallta area at Station A
A A: Area at Station A

2. Maximum Daily Rain
There are two calculations to determine the maximum daily rain, they are Gumbel Method and Log Person III with the following equation [9]:

Gumble:
$$XT = \bar{x} + sK \quad (2)$$
Log Person III:
$$XT\ logs = logs\bar{x} + K \quad (3)$$

Information :
XT = Planned rainfall for the period of the year
$\bar{x}$ = average sample price
S = standard deviation (standard deviation) of the sample

3. Probability Distribution Testing
The probability distribution test is carried out to determine which probability distribution equation can be used to show the statistical distribution of the sample data being analyzed [10]. Testing the suitability of rain data can be determined by means of Chi-square and Kolmogorov Smirnov [11].

4. Rain Intensity
Rain intensity analysis is determined by three methods, namely: Bell, Van Breen, and Hasper Weduwen

5. Land Use
This understanding shows that land is a landscape where all living things live and survive by making use of it [12].

6. Flow Coefficient
The value of the flow coefficient is used to determine the design debris in the testing area [13]. For determining the flow coefficient with the following equation:
$$C = \frac{C1.A1 + C2.A2 + C3.A3 + \cdots Cn.An}{A1 + A2 + A3 + \cdots An} \quad (4)$$
Information :
C = flow coefficient
A = catchment area (m^2)

7. Planning Debt
In drainage planning, in general, the discharge calculation used is the rational method. Basically the calculation of the design discharge is used to determine the value of the peak flood plan discharge in an area. The formula for calculating the planned flood discharge using the rational method is as follows[9].
$$Q = 0.0027785\ CIA \quad (5)$$
Q = Planning debt (m^3 /sec)
C = Surface flow coefficient
I = Rainfall intensity (mm/hour)
A = Watershed area (ha)

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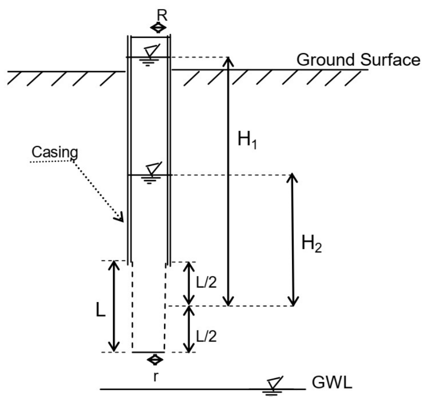
8. Insitu permeability falling head
   Permeability is defined as a property of a material that allows seepage flow from a liquid in the form of water or oil to flow through the pore cavity [14]. The permeability value was obtained from the results of the soil sample test using the Falling Head method. The equation for determining the permeability value of the soil is used as follows:



$$k=\frac{(2.3)^2R^2}{2L(t_2-t_1)}\log\left(\frac{L}{r}\right)\log\left(\frac{H_1}{H_2}\right)$$

if $L > 8r$

Where :

k :Coef. of Permeability (cm/sec)
R :Radius of Casing (cm)
r :Radius of Hole (cm)
H_1:Head of Water (Initial Reading)(cm)
H_2:Head of Water (Final Reading)(cm)
L :Length of Test Section (cm)

Figure 1. Insitu Permeability falling head
Source: Azizah Rachmawati, 2018

Infiltration well planning can be determined by the dimensions of the infiltration well according to the planned model. The types of infiltration wells are:

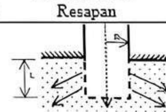
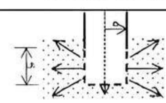
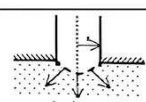
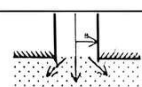
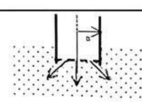
Sumur Resapan	Bentuk Sumur Resapan	Debit Resapan (Q_0)	Keterangan
SRB1		$Q_0=\frac{2.\pi.L.K.H}{\ln\left(\frac{L}{R}+\sqrt{1+\left(\frac{L}{R}\right)^2}\right)}$	L = H dan permukaan tanah kedap air
SRB2		$Q_0=\frac{2.\pi.L.K.H}{\ln\left(\frac{L}{2R}+\sqrt{1+\left(\frac{L}{2R}\right)^2}\right)}$	L = H dan permukaan tanah tidak kedap air
SRB3		$Q_0 = 2.\pi.R.K.H$	L=0, dasar sumur resapan berbentuk cembung, dan permukaan tanah kedap air
SRB4		$Q_0= 4.R.K.H$	L=0, dasar sumur resapan berbentuk datar, dan permukaan tanah kedap air
SRB5		$Q_0= 5,5.R.K.H$	L=0, dasar sumur resapan berbentuk datar, dan permukaan tanah tidak kedap air

Figure 2. Types of Recharge wells
Source: Sunjoto, 2002; in Suripin, 2004

In selecting the type of infiltration well, there are several provisions that must be considered, they are: land use conditions, soil vulnerability, and surface water flow and ground water flow. There is the formula example to determine the capacity of an infiltration well:

$$H = \frac{Q}{FK}\left[1-e^{-\left(\frac{FKT}{\pi R^2}\right)}\right] \tag{7}$$

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Information :
H : water level in the well (m),
Q : inlet water debit (m3/sec),
F : geometric factor (m),
K : soil permeability coefficient (m/s),
Q : streaming time (seconds),
R : radius of the well (m).
The formula for determining the effectiveness of reduction is as follows:

$$\text{Qef} = \frac{Q\ tot}{Q\ renc}\, x\ 100\% \qquad (8)$$

Qef : Effectiveness of reduced debit
QTot : Planned whole well debit (m3/sec),
Qrenc : Planned debit (m3/sec),

3. Results and Discussion

3.1. Polygon Thiessen Method

Analysis of the regional average maximum rainfall was carried out using the Polygon Thiessen method. The way to calculate the regional average maximum daily rainfall or Thiessen Coefficient (C) is by taking into account the area covered by the station in question.

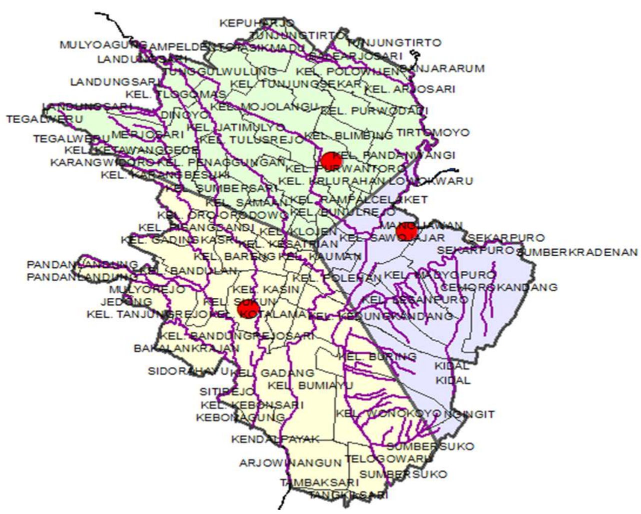

Figure 3. Poligon Thiessen Map
Source: Analysis ArcGis 10.8 2023

After the Thiessen coefficient for each rain station is known, it is also necessary to know the average maximum rainfall for each rain station using the Polygon Thiessen method. The following is the Thiessen Polygon calculation formula:

$$\text{R} = \frac{(R1\ x\ \text{A1})+(R2\ x\ \text{A2})+(R3\ x\ \text{A3})}{\text{C1+C2+C3}}$$

$$\text{R} = \frac{(\ 85\ x\ 0.37165\ )+(\ 101\ x\ 0.22167\ )+(\ 111\ x\ 0.40666\ )}{0.37165 \quad .22167+0.40666}$$

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R = 457.1628 mm

the complete calculation of average rainfallis is as follows:

Table 1. Regional Rainfall Calculation *Polygon Thiessen Method*

YEAR	STA. CILIWUNG	STA.SAWOJAJAR	STA.SUKUN	Rainfall Maks Average (mm) (R)
Koef. *Thiessen*	0.37165	0.22167	0.40666	
2013	85	101	111	457.1628
2014	100	134	115	539.4081
2015	65	170	86	521.8303
2016	75	122	153	556.1032
2017	105	132	100	515.5906
2018	95	94	126	479.4696
2019	93	135	90	492.3285
2020	145	125	81	510.8943
2021	95	133	78	470.5407
2022	105	82	123	462.4258

Source : Analysis, 2023

3.2. Design Discharge Calculation

Calculated rainwater runoff discharge, there are several things that must be used, namely the land use of the research area, so that we can determine the flow coefficient in the research area. Determining the discharge of rainwater runoff using the rational method;
Qah = 0.278 x C x I x A. The work steps are as follows.

Watershed Area Calculation (A)

Calculation of the area of the drainage area uses the Arcgis 10.8 application following the calculation steps:

1. Collect data that will be used in making the map that will be used, namely administrative data, road network data, this data is in the form of a shp file.
2. Enter data into the ArcGis 10.8 application

a. Input the shp file used

b. Input the layer into ArcGis 10.8 so that the lines and flow boundaries appear.

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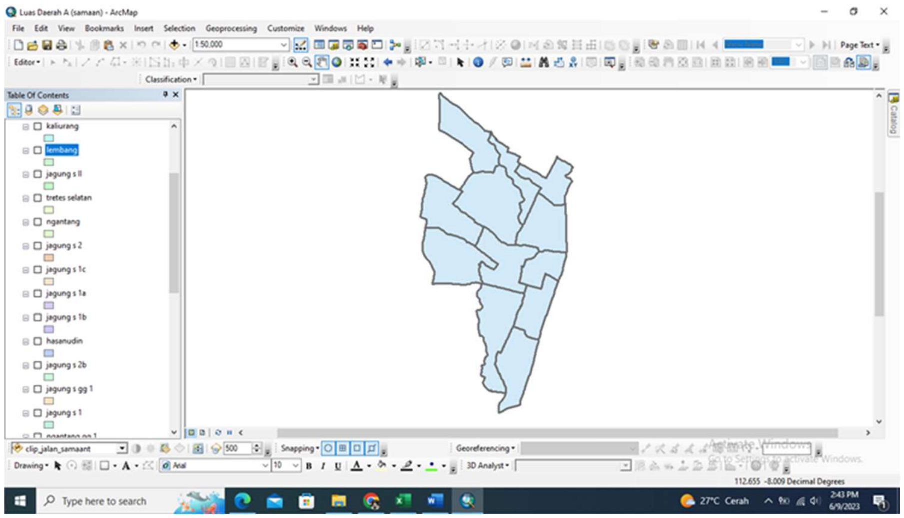

Figure 4. Location Points for Finding Area
Source: ArcGis 10.8 Application, 2023

After carrying out data processing, the area of the drainage area (A) can be seen in the following table:

Table 2. Watershed Area calculation (A) Gadingkasri Sub distric

No	Street	Code Chanel	Leght(m)	Watershed Area Calculatin (A)	
				Km^2	Ha
1	Jl. Galunggung	SS.GLG	1030	0.21000	21.0000
2	Jl. Bondowoso	SS.BDO	534.2	0.06553	6.5525
3	Jl. Simpang Wilis	ST.SWS	443.3	0.01672	1.6722
4	Jl. Gading	ST.GIG	354.4	0.01927	1.9271
5	Jl. Raya Dieng	SS.RDG	273.2	0.02990	2.9901
6	Jl. Pulosari	ST.PLI	221.2	0.02691	2.6906
7	Jl. Wilis	ST.WLS	654.3	0.06306	6.3059
8	Jl. Kawi	SS.KW	189.1	0.03349	3.3491
9	Jl. Semeru	SS.SMU	168.7	0.05229	5.2285
10	Jl. Retawu	SS.RTU	493.1	0.12687	12.6872
11	Jl. Lumajang	ST.LUG	143.4	0.01250	1.2500
12	Jl. Gresik	ST.GK	382.8	0.01133	1.1334
13	Jl. Gede	SS.GE	298.3	0.01233	1.2333
14	Jl. Surabaya	SS.SBY	416	0.03889	3.8889
15	Jl. Mojokerto	ST.MJO	263.9	0.02009	2.0094
16	Jl. Jombang	ST.JBG	278.8	0.05207	5.2065
17	Jl. Kawi Atas	SS.KWA	371.3	0.05529	5.5293
18	Jl. Besar Ijen	SS.BIN	530.3	0.11862	11.8620

Source: Analysis and ArcGis, 10.8 2023

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Table 3. Drainage channel evaluation results

No	Code	Chanel	Qeks (m^3/dt)	Qr (m^3/dt)	Qdifference (m^3/dt)	Condition
1	SS.GLG	Jl. Galunggung	1.46305	9.22113	-7.75808	overflows
2	SS.BDO	Jl. Bondowoso	6.42429	28.99941	-22.57512	overflows
3	ST.SWS	Jl. Simpang Wilis	4.50144	1.34165	3.15980	Not overflowing
4	ST.GIG	Jl. Gading	10.06894	9.02877	1.04017	Not overflowing
5	SS.RDG	Jl. Raya Dieng	8.98332	14.64522	-5.66190	overflows
6	ST.PLI	Jl. Pulosari	4.99177	13.73533	-8.74356	overflows
7	ST.WLS	Jl. Wilis	26.12168	28.46456	-2.34287	overflows
8	SS.KW	Jl. Kawi	21.59540	17.69030	3.90511	Not overflowing
9	SS.SMU	Jl. Semeru	9.00264	28.36626	-19.36361	overflows
10	SS.RTU	Jl. Retawu	50.14999	60.72482	-10.57483	overflows
11	ST.LUG	Jl. Lumajang	12.39945	7.06533	5.33413	Not overflowing
12	ST.GK	Jl. Gresik	15.17823	5.24757	9.93066	Not overflowing
13	SS.GE	Jl. Gede	51.58242	5.94599	45.63643	Not overflowing
14	SS.SBY	Jl. Surabaya	5.09599	17.78755	-12.69156	overflows
15	ST.MJO	Jl. Mojokerto	9.14024	9.90551	-0.76527	overflows
16	ST.JBG	Jl. Jombang	8.89264	25.40632	-16.51368	overflows
17	SS.KWA	Jl. Kawi Atas	15.41149	25.71895	-10.30746	overflows
18	SS.BIN	Jl. Besar Ijen	12.89574	9.85214	3.04360	Not overflowing

Source: Analysis, 2023

4. Results and Discussion

Recharge Wells Planning

Example of calculation for planning an infiltration well on the ST. NTG1 channel:
The planned discharge (Qr) = 2.15494 m^3/s
Existing channel capacity discharge (Qeks) = 0.39237 m^3/s
Soil permeability coefficient (K) = 2.5 cm/hour
= 0.0007 cm/s
Incoming water discharge (Qinput)
In planning an infiltration well, it is usually done by first calculating the discharge. The method used to determine debit is the USSCS Rational method (1973). (Goldman et.al., 1986).

Q = Catap x I x Aatap
Qinput = Catap x I x Aatap
= 0.95 x 0.00016 x 4943
= 0.7563 m^3/s

Dimensions of infiltration wells
The dimensions of the infiltration well are planned in the form of a circle made of buis concrete and the bottom uses a porous (soil) wall with dimensions:
Diameter = 1m
Radius = 0.5 m
Depth of infiltration well
Well depth (H) = 1.6 m (rainwater absorption wells are used for groundwater depths of 1.2 – 2 m (SNI 8456.2017)). In planning the research location, an average depth of 1.6 m was used.
Shape factors (F)

F = 2 x π x r
= 2 x 3.14 x 0.5
= 3.14 m

The discharge is absorbed by the infiltration well

Qinfil = F x K x H
= 3.14 m x 0.0007 m/s x 1.6 m

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$= 0.0035\ m^3/s$

The discharge is accommodated by the infiltration well

Qaccommodated = Qinput – Qinfil
= 1.7626 – 0.0035
= 1.7591 m^3/sec

Infiltration well capacity

The capacity of the infiltration well has a circular cross section, with a radius = 0.5 m and a depth of 1.6 m. So, it has the following capacities:

Vsr = 1/4 x π x D^2 x H
= 0.25 x 3.14 x 1^2 x 1.6
= 1.256 m^3

Number of wells:

n = Q_input/Vsr
= 0.7563/1.256
= 0.6021 units
= 1 unit

Distance to infiltration wells

Distance = (length of channel)/(number of infiltration wells)
= 116/1
= 116 m

Infiltration well efficiency

Efficiency = Q_planned/Q_accommodated
= 2.15494/1.7591 x 100%
= 70,1 %

5. Conclusion

From the results of the recharge well drainage planning as a flood prevention in Klojen distric, Malang City, then the results of this analysis can be concluded as follows: 1) The estimated rainfall in Samaan Village, Bareng Village and Gadingkasri Village is 592,112 mm/day with a return period of 10 years. Meanwhile, the dirty water discharge in Samaan Village was 55.5671 m^3/s, in Bareng Village it was 69.7182 m^3/s, and in Gadingkasri Village it was 47.3422 m^3/s. 2) The design flood discharge in Samaan Village is 56.7521 m^3/s, in Bareng Village it is 83.3086 m3/s, and in Gadingkasri Village it is 60.7248 m^3/s. 3) From the results of the analysis and evaluation at the research location, there are several drainage channe points where the water overflows when there is high rainfall and the flow is irregular. This is caused by drainage channels that are unable to accommodate high water discharges and planning the slope of the channel that is not in accordance with the contour conditions in the field. So, recharge wells are a solution to overcome drainage problems in Samaan Village, Bareng Village, and Gadingkasri Village. 4) In this research, it is planned to use concrete buisses with a diameter of 0.5 m and a height of 1 m. The number of infiltration wells in Samaan Village is 12, Bareng Village is 28, and Gadingkasri Village is 26. So, the total number of absorption wells is 66.

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