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Utilization of Rainwater Puddles at Campus I State University of Malang

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Abstract. Heavy rain that occurs on the State University of Malang campus often results in puddles. With the large water catchment area in the campus area and the many locations where rainwater pools, it is necessary to research how much rainwater can be collected. The methodology used includes collecting rain data, observing inundation locations, calculating rain using the ranking method, rational method debit calculations, water balance calculations, and storage size calculations. From the survey results, the locations that can be used as reservoirs consist of 14 locations. The area of the catchment area that has the potential to drain water into the reservoir is 69,845.10 m^2. The storage capacity calculation results obtained: G1 = 178.50 m^3, G1 = 80 m^3, G3 = 75 m^3, G4 = 108 m^3, G5 = 97.5 m^3, G6 = 93.6 m^3, G7 = 84 m^3, G8 = 22.5 m^3, G9 = 67.2 m^3, G10 = 83.2 m^3, G11 = 41.6 m^3, G12 = 36.4 m^3, G13 = 65 m^3, G14 = 65 m^3. The amount of standing water that can be accommodated in the storage pond is 852.72 m^3. The amount of standing water that can potentially be stored for 1 year is 19,553.98 m^3.

1. Introduction

Heavy rain that occurs on the State University of Malang campus often results in puddles. Puddles generally come from the collection of water that cannot flow into drainage. Observations in the inundation area showed that the rainwater flowed from the campus road. Most campus roads use concrete paving materials. Campus road paving is a cause of rainwater not seeping into the ground. The campus road has a drainage channel beside it. Another problem that causes flooding in the campus area is the small number of drainage holes. The topography of the campus area has a high slope. This causes the water flow on campus roads to have quite high speeds. The water that flows on the campus road then leads to the location of the puddle. These puddle areas generally have drainage holes but are usually small and few in number.

Flooding in several locations often disrupts the activities of road users. Rain forms puddles after 15 minutes to 20 minutes from the start of the rain. Puddles vary in height from 5 cm to 20 cm. The water flow on the road has water levels ranging from 1 cm to 5 cm. The flood receding time ranges from 30 minutes to 60 minutes after the rain stops. The standing

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water flows into the drainage channel. With the large water catchment area in the campus area and the many locations where rainwater pools, it is necessary to research how much rainwater can be collected. Collected rainwater can be placed in a reservoir. The collected rainwater can later be used as a campus raw water reserve. Raw water can be used as water for plants in campus parks. Watering plants in campus parks uses deep well water.

This research aims to determine the potential amount of water that can be collected. The methodology used includes collecting rain data, observing inundation locations, calculating rain using the ranking method, rational method debit calculations, water balance calculations, and storage size calculations. The results of this research can be used as a consideration in utilizing rainwater that comes from puddles on the roads at the State University of Malang Campus.

1.1. Previous Studies

1.1.1. The Potential and Multifunction of Rainwater Harvesting in Schools for Urban Infrastructure

Schools as one of the large infrastructures spread across an area have great potential to be used as a means of harvesting rainwater. Rainwater harvesting activities can also be used as an educational tool in the context of conserving water resources in schools [1].

1.1.2. Evaluation of The Semarang City Environmental Agency's Rain Water Harvesting Program

The Semarang City Government is trying to control the impacts of climate change, one of which is the Rain Water Harvesting Program by the Semarang City Environmental Agency. This program aims to address the five main issues of the impact of climate change in the city of Semarang, namely reducing floods, tidal waves, drought, landslides and infectious disease outbreaks [2].

1.1.3. Planning for Rainwater Harvesting As An Alternative Water Source on The Diponegoro University Campus

Rainwater harvesting is planned as an alternative water source in the UNDIP area so that it is hoped that there will be a reduction in the use of groundwater as the main source of meeting water needs in the UNDIP Tembalang area. The use of groundwater to meet water needs in the UNDIP Campus area for 2014/2015 was 2.23 lt/s, exceeding the permitted optimum debit for well water withdrawal, namely 0.2-1 lt/s. Based on this, plans were made for a rainwater building with a volume of 245 m^3 with dimensions of 7m x 7m x 5m and dimensions of an infiltration well with a diameter of 1.5 m and a depth of 3 m [3].

1.1.4. *Rain Water Harvesting Techniques as An Alternative to Save Water Resources in The DKI Jakarta Region*

Jakarta as a metropolitan city has complex problems related to the water resources crisis. Rainwater harvesting techniques have become an important part of the water resources management agenda in order to overcome water imbalances such as lack of rain and drought (water shortage), clean water supply for the world community, as well as overcoming floods and droughts [4].

1.1.5. Development of a Rainwater Harvesting System for Providing Clean Water in Selatpanjang Riau

The aim of this research is to analyze the potential availability of rainwater sources and the clean water needs of residents in the Selatpanjang area in 2030. Development of a rainwater harvesting system for anticipate shortages of clean water during the dry season and explain the relationship between environmental, social and economic aspects related to rainwater harvesting systems[5].

2. Metodology

The steps required in this research activity are literature studies, inundation surveys, Malang State University campus maps, and daily rainfall data at rain posts in Malang City, namely the Blimbing rain post, the Sukun rain post, and the Dau rain post.

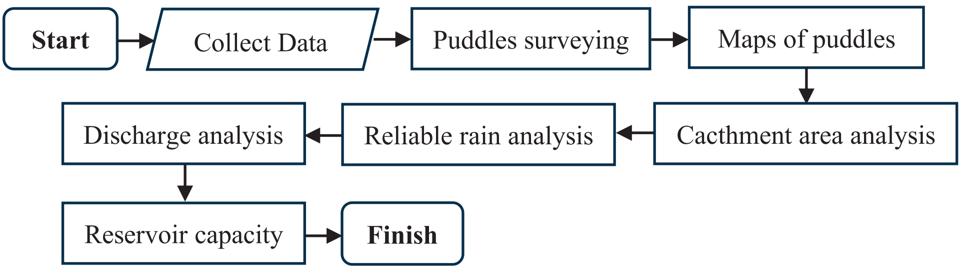

Fig. 1 Research flow diagram

3. Analysis

3.1. Puddles Surveying

Observations in the field were carried out when it started to rain. The method used in this survey is by tracing the flow of rainwater on the surface to the location where the puddles collect. During the survey, the height of the puddle was also measured.

(a) (b)

Fig. 2 Puddles Surveying : (a) Street in front of A21 Building ; (b) Street in front of B2 building

The result of the inundation survey is an inundation map. This inundation map was compiled using QGIS software. The coordinate system used is WGS84 / UTM Zone 49S. The inundation map can be seen in the following image :

Fig. 3 Maps of Puddles

3.2. Reliable Rainwater

Determining the post of rain that affects the Malang State University area can be calculated using the Thiessen Polygon method. For more details, the Thiessen polygon analysis can be seen in the following image :

Fig. 4 Polygon Thiessen of Rain Post

The rain post that can represent the characteristics of rain for the State University of Malang area is the Blimbing rain post. From selecting the rain post, it was then continued with the use of rain data from the Blimbing rain post.

The next analysis is the mainstay rain calculation. If the mainstay discharge for irrigation purposes is set at 80% then the risk of failure is 20%. The total rainfall data for one year is then entered into the table. Then the total rainfall data for one year is sorted from largest to smallest. Then calculate the probability by means:

$$Probability = \frac{number\ of\ year}{maximum\ number\ of\ years}\ x100\ \% \qquad (1)$$

$$Probability\ 1 = \frac{1}{15}\ x100\ \%$$

$$Probability\ 1 = \ 6.67\ \%$$

As above the method used for the next annual rainfall amount. Calculating the probability, it was found that reliable rain in 2008 had a probability value of 80%. The results of reliable rain calculations can be seen in the following table :

Table 1. Reliable Rainwater

Years	**Rainwater (mm)**	**Rank of Rainwater (mm)**	**Probabilitas (%)**	**Rank of The Years**
2008	1775	3865	6.67	2021
2009	1727	3846	13.33	2010
2010	3846	3197	20.00	2014
2011	2074	3014	26.67	2022
2012	1547	2535	33.33	2016
2013	2458	2458	40.00	2013
2014	3197	2277	46.67	2020
2015	1667	2272	53.33	2017
2016	2535	2142	60.00	2019
2017	2272	2074	66.67	2011
2018	1847	1847	73.33	2018
2019	2142	1775	80.00	2008
2020	2277	1727	86.67	2009
2021	3865	1667	93.33	2015
2022	3014	1547	100.00	2012

3.3. Reliable Discharge

The mainstay debit calculation in this research uses the rational method. This calculation is based on the conditions of the catchment area, namely the length of the water flow, the area of the catchment area, land use and the slope of the land.[6]

The rational calculation begins with calculating the time of concentration (Tc) using the Kirpich method :

$Tc = 0.01947 * L^{0.77} * S^{-0.385}$ (2)

Explanation :

L = longest of flow (m) ; S = slope of terrain

For puddle location 1 (G1) the concentration time can be calculated as follows :

Data :

L = 452 m ; Slope of terrain = 0.01327

Calculation :

$Tc = 0.01947 * 452^{0.77} * 0.01327^{-0.385}$

Tc = 11.388 minute = 0.190 hour

Then estimate of rain intensity. Rain intensity used the mononobe formula :

$$I = (R24/24) * (24/Tc)^{2/3} \quad (3)$$

Explanation :

I = rain intensity (mm/hour) ; R24= rain of daily (mm)

Tc = time of concentration (hour)

Then estimate of rain intensity at 30 march data of rainwater (maximum rainwater of 2008 year). Estimate of rain intensity used the mononobe formula :

Data :

R24 = 95 mm ; Tc = 0.190 mm/hour

Calculation :

$I = (95/24) * (24/0.190)^{2/3}$

I = 99.72 mm/hour

Then estimate of flow discharge used the rational formula :

$$Q = 0.278 * C * I * A \quad (4)$$

Explanation :

Q = discharge (m^3/s); C = flow coefficient; I = rain intensity (mm/hour)

A = large of catchment area (km^2)

Then continue estimate of flow discharge at G1 puddles location.

Data :

C = 0.95 (concrete paving) ; I = 99.72 mm/hour ; A = 9867.25 m^2 = 0.009867 km^2

Calculation :

Q = 0.278 * 0.95 * 99.72 * 0.009867

Q = 0.260 m^3/s

3.4. Storage Capacity

To convert discharge into volume of water that can be accommodated, it can be calculated using the equation :

volume of water that can be accommodated = Q * Tc * 3600 (5)

Then continue estimate of volume of water that can be accommodated at G1 puddles location:

Volume of water = 0.260 * 0.190 * 3600

Volume of water = 177.56 m^3

Then estimate of storage capacity used the rational formula :

Storage capacity = long * wide * tall $\geq$ water volume (6)

Explanation :

long = long of storage (m) ; wide = wide of storage (m) ; tall = tall of storage (m)

Then continue estimate of storage capacity at G1 puddles location :

Storage capacity = 21 * 5 * 1.7 $\geq$ 177.6 m^3

Storage capacity = 178.50 m^3 $\geq$ 177.6 m^3

For calculations at other puddle locations, it can be calculated in the same way. Calculations for other inundation locations can be seen in the following table:

Table 2. Estimation of storage capacity

Puddles	Area (m^2)	Tc (hour)	I (mm/ hour)	Q (m^3/s)	Volume of water (m^3)	Long (m)	Wide (m)	Tall (m)	Storage Capacity (m^3)
G1	9867.3	0.190	99.7	0.260	177.56	21	5	1.7	178.5
G2	4174.3	0.206	94.4	0.104	77.19	10	5	1.6	80
G3	4211.5	0.183	102.3	0.114	74.81	10	5	1.5	75
G4	7601	0.083	173.2	0.348	103.79	18	4	1.5	108
G5	7023	0.083	173.2	0.321	95.89	13	5	1.5	97.5
G6	5460	0.147	118.4	0.171	90.18	12	6	1.3	93.6
G7	4785	0.147	118.3	0.150	79.05	12	5	1.4	84
G8	1909	0.045	260.6	0.131	21.25	15	1	1.5	22.5
G9	5396	0.057	223.3	0.318	64.69	21	2	1.6	67.2
G10	5780	0.083	173.7	0.265	78.81	13	4	1.6	83.2
G11	3153	0.069	196.6	0.164	40.41	8	4	1.3	41.6
G12	2459	0.091	163.4	0.106	34.57	7	4	1.3	36.4
G13	4045	0.125	131.4	0.140	63.41	13	5	1.0	65
G14	3981	0.117	137.8	0.145	60.90	10	5	1.3	65

The use of maximum rainfall as the basis for calculating storage capacity is due to the availability of land on the State University of Malang campus. The total catchment area that collects rainwater is 69,845.10 m^2. The amount of water that can be stored from the analysis above is 852.72 m^3. Meanwhile, if calculated from 365 days of rain data, the amount of water that can potentially be stored is 19,553.98 m^3.

The calculation of storage capacity can be seen in the following picture :

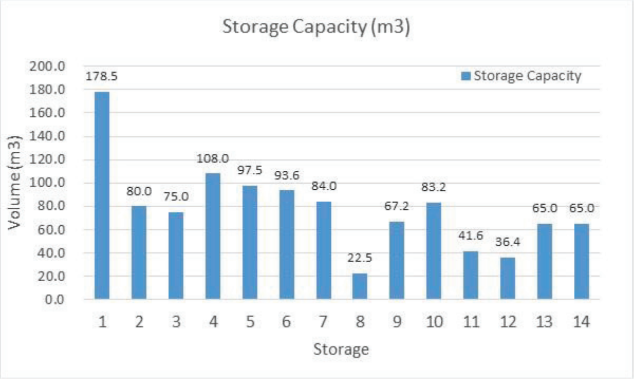

Fig. 5 Storage capacity

4. Conclusion

Rainwater that becomes puddles has the potential to be stored in reservoirs. From the survey results, the locations that can be used as reservoirs consist of 14 locations. Distribution of storage locations based on the point where standing water collects. The rain post that affects the State University of Malang campus is the Blimbing rain post. Annual rainfall data was obtained from 2008. The total catchment area that has the potential to drain water into the reservoir is 69,845.10 m^2. The results of the storage capacity calculations were obtained: G1 = 178.50 m^3, G1 = 80 m^3, G3 = 75 m^3, G4 = 108 m^3, G5 = 97.5 m^3, G6 = 93.6 m^3, G7 = 84 m^3, G8 = 22.5 m^3, G9 = 67.2 m^3, G10 = 83.2 m^3, G11 = 41.6 m^3, G12 = 36.4 m^3, G13 = 65

m^3, G14 = 65 m^3. The amount of standing water that can be stored in the reservoir is 852.72 m3. The amount of standing water that could potentially last for 1 year is 19,553.98 m^3. The calculation of storage dimensions does not use the amount of water stored for 1 year, but uses the amount of water from the maximum daily rainfall. This was done due to consideration of land availability on the Malang State University Campus.

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