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To cite this article: Novitasari Novitasari and Holdani Kurdi 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **999** 012010

Flood Mitigation in Banjar Regency, South Kalimantan, Indonesia in 2021: Between Hydro-meteorological factor and Anthropogenic factor

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Abstract. The year 2021 in Banjar Regency and several other regencies in South Kalimantan Province opened with floods disaster. High rainfall caused the river to overflow; one of the rivers that overflowed was the Martapura River in Banjar Regency. The flood in 2021 is not the first flood disaster to occur, but a floods disaster that has occurred frequently. This flood is a fairly large flood compared to the previous flood. The areas affected by the large flood in Banjar Regency are in the Districts of Sungai Tabuk, Martapura Kota, East Martapura, West Martapura, Astambul, Karang Intan, and Pengaron. The method used in this research is to analyze the hydro-meteorological using the rainfall-runoff model, and the anthropogenic factors in the flood events in Banjar Regency be approached by the value of the *C* coefficient. The hydro-meteorological factors as natural factors cannot be predicted. The extreme rainfall on January 14, 2021 as 255.3 mm is higher than 100-years return period as 244.716 mm. Its caused biggest flood disaster in January 2021. The anthropogenic factors caused by humans can be reduced. One of the anthropogenic factors that have the most impact on any flood event is land-use change. Land-use change causes rainwater that falls cannot infiltrate into the ground. One of the most common community activities is to close the yard and the drains so that rainwater does not have access to penetrate the ground. Second, the conversion of agricultural land, and swampland into residential and industrial areas. The third factor that is no less important is the role of the community in development that is not environmentally friendly, one of them by dredging for houses or other buildings. These three anthropogenic factors cause the *C* value to increase, and it increases the flood discharge.

Keywords: hydro-meteorological, anthropogenic, land-use, flood mitigation, The Banjar Regency

1. Introduction

Flood disaster in South Kalimantan is a disaster that occurs almost every year. Based on research in 2019 active community participation in flood preparedness in various areas in South Kalimantan is quite high at 60.78% in the form of energy supply and financing assistance [1]. Selama ini masyarakat juga sudah beradaptasi dengan banjir, salahsatunya adalah dengan bentuk rumah yang dibuat tinggi [2]. round. [1]. So far, the community in South Kalimantan has also adapted to flood disaster, one of which is the pattern of houses that are made high [2].

The flood that occurred in South Kalimantan in mid-January 2021 was a fairly large flood. The flood disaster covered a very wide area. Floods that occurred covered almost all regencies and cities in South Kalimantan Province, with varying heights from 0.5 to 3 meters. The South Kalimantan Province is categorized as a flood response status on January 14, 2021. This flood disaster is a flood that occurs due to rainfall with a fairly high intensity in several locations and high tides of sea water simultaneously [3][4]. Continuous rainfall took place from 10 to 16 January 2021 in several locations in South Kalimantan. This is an external factor caused by hydro-meteorological factors. Based on extreme rain data recorded at BMKG Online for 2 stations in South Kalimantan, namely the Banjarbaru Climatology Station of 255.3 mm on January 14, 2021 and the Syamsudin Noor Meteorological Station of 249 mm as of January 14, 2021 [6].

One of the causes of flooding besides the rainfall intensity as the hydrometeorology factor is the anthropogenic factors, namely land use changes caused by humans activities. Based on global forest watch, South Kalimantan lost 2.60 kha of primary forest in 2020. From year 2001 to 2020, South Kalimantan lost 815 kha of forest area [7]. Banjar District lost lost 10.2kha of humid primary forest from year 2002 to 2020, as 12% decreased of total area of forest [8]. Land changes caused by human activities are anthropogenic factors that must be considered. Spatial research that has been conducted in Kalimantan has found that the frequency of flooding is associated with the land use changes into the development areas over the last 30 years [9]. A fairly large flood disaster occurred in Banjar Regency which covered almost all sub-districts with various flood heights. The highest flood disasters occurred in 7 sub-districts, consisting of Sungai Tabuk, Martapura Kota, East Martapura, West Martapura, Astambul, Karang Intan and Pengaron sub-districts. The government has also implemented a strategy in managing watersheds affected by floods in Banjar Regency [5].

Most of the forest and swamp loss in South Kalimantan is caused by massive land conversion. This land conversion causes the loss of ground cover and leaves the land open and vulnerable to flooding and drought. Water does not have a chance to enter the ground during the rainy season. In the dry season, water that is not stored in the soil accelerates the drying of groundwater which triggers extreme drought. One of the most affected areas in Banjar Regency is the Tambak Anyar Traditional Polder, which in recent years has experienced regular flooding [10]. Scope of problem in this research is 1. The highest rainfall intensity as hydrometeorology factor, 2. The land use change in Banjar Regency as anthropogenic factor by human activities, 3. The lower infiltrate water in land and higher overflowing to the Martapura river. The three scope of problems caused flood disaster in 2021.

The purpose of this study was to determine the relationship between hydrometeorological factors and anthropogenic factors in flood disaster in Banjar Regency. This study tries to find a relationship between hydrometeologoly and anthropogenic factors to overcome the flood disaster that occur in Banjar Regency.

2. Method

The method used is direct observation in 7 sub-districts in Banjar Regency with 3 villages as sample points for taking a questionnaire on anthropogenic factors. The next method used in this service is to analyze external factors in the rainfall runoff model. The rainfall data obtained from BMKG online [6].

The analysis was carried out using the frequency analysis model from a 28-year rainfall data series to determine rainfall design. The second method in this research is using mononobe model to design rainfall intensity from rainfall design. The analysis followed by the rational method to design flood descharge. This analysis is equipped with a runoff coefficient based on the results of a field survey of 68 villages in Banjar Regency [11][12][13].

3. Results

Banjar Regency with an area of ±4,668.50 Km^2, is the 3rd largest area in South Kalimantan Province, after Kotabaru Regency and Tanah Bumbu Regency. Banjar Regency consists of 20 sub-districts, 277 villages and 13 sub-districts. Banjar Regency is bordered by Hulu Sungai Selatan Regency and Tapin Regency in the north, by Banjarbaru City and Tanah Laut Regency in the south, by Kotabaru Regency and Tanah Laut Regency in the east, and by Batola Regency and Banjarmasin City in the west [14]. Research area of Banjar Regency shown in Figure 1.

The Banjar Regency area is mostly dominated by climate type B, with annual rainfall ranging from 2,000 – 2,500 mm, rainfall per day of rain ranging from 9.5 – 18.6 mm/rainy day and rainy days per month on average ranging from 12.3 – 15.6 days/month. Air pressure ranges from 1,007.3 – 1,014.3 millibars and air humidity ranges from 48% – 100%. Meanwhile, the air temperature ranges from 20ºC – 36.2ºC, and the average wind speed is 5.5 knots. The percentage of solar radiation ranges from 21% – 89% [15].

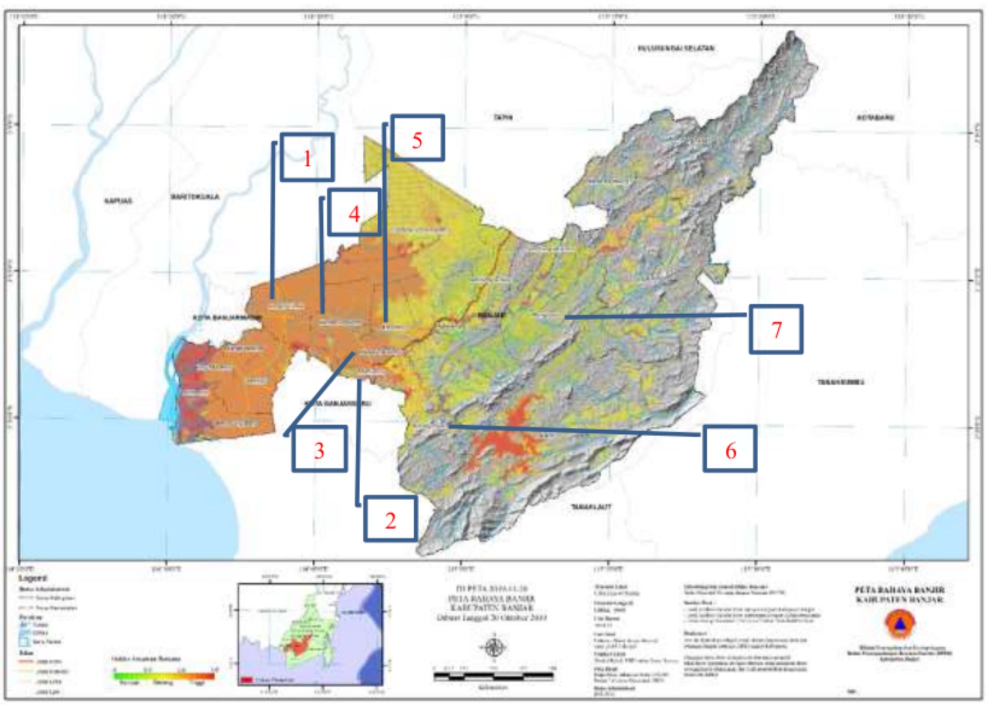

Figure 1. Research area of Banjar Regency [16]

The questionnaire surveys and direct interviews were conducted in 15 sub-districts represented by 3 villages per sub-district with a total of 68 villages. The results of this field study were taken from the 7 most affected sub-districts and used to analyze the influence of anthropogenic factors which are one of the aspects considered aggravating flood conditions in Banjar Regency. The seven sub-districts include Sungai Tabuk, Martapura Kota, East Martapura, West Martapura, Astambul, Karang Intan and

Pengaron Districts. The survey was conducted in April and May 2021. The existing condition in seven district based on land use survey result shown in Table 1. The percentage of the house yard area that is not covered can be seen in the Figure 2.

Table 1.. Existing conditions in seven sub-districts based on land use survey

No	District	Flood	Landcover	Description	Condition overview
1	Sungai Tabuk	± 1 – 1.5 m	21.67%	Abandoned land is converted into housing, flood events are still ongoing	
2	Martapura Kota	± 30 cm	25.00%	Land conversion with the presence of settlements on the banks of the river	
3	Martapura Timur	± 0.7 - 1.5 m	23.33%	Land conversion and rice fields are still submerged	
4	Martapura Barat	± 80 cm	30.00%	Conditions are still flooded and the rice fields are submerged	
5	Astambul	± 1 – 1.5 m	11.67%	The conditions are still flooded and rice fields are submerged	
6	Karang Intan	± 1 – 3 m	18.33%	The condition of abandoned land and floods still occur	

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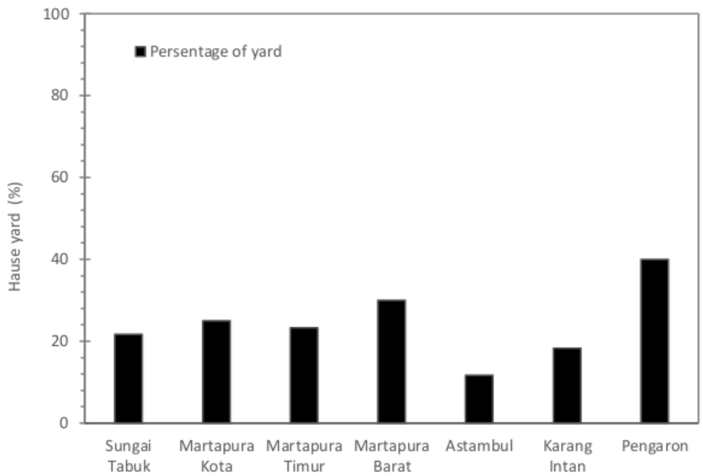
7	Pengaron	± 2.5 m	40.00%	There have been many crop failures in the community's rice fields and clogged rivers t	



The anthropogenic factors caused by human activities in changing land use are one of the most important internal factors. Observational conditions show that the percentage of open land in the form of yards and not covered with plants is quite high, reaching 40% of the total area. The absence of ground cover means that rainwater cannot seep into the ground. Some of the activities seen during the survey were 1. closing the yard area with cement so that water could not seep into the ground, 2. changing land use from rice fields or swamp areas that should be inundated into built-up areas or housing or industrial areas, and 3. There are still many people who build houses by filling them up to elevate their houses, not by building tall houses like local wisdom in Kalimantan. The reduction in land cover above causes the loss of the ability to absorb water during extreme rains.

In addition to direct observation, analysis was also carried out on external factors that triggered excess water in Banjar Regency and caused flooding, namely rainfall. Rainfall data series were collected from 1993 to 2020 from BMKG Data and BMKG Online [6]. The maximum daily rainfall for 28 years is presented in Figure 3 below.

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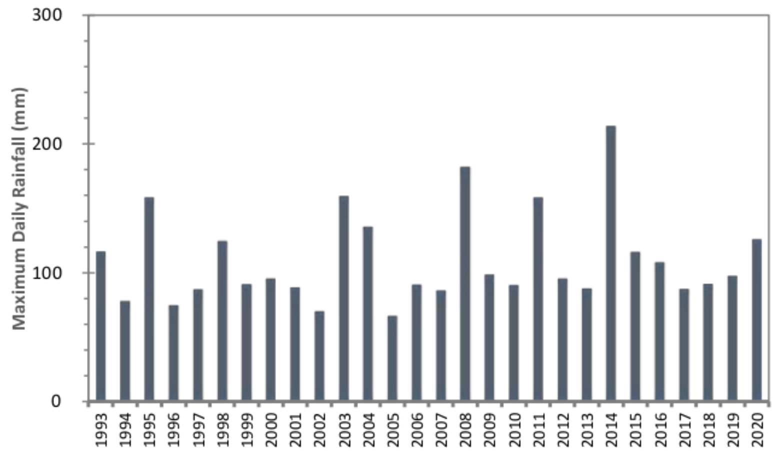

Figure 3. Maximum daily rainfall year 1993 to 2020

The external factor analysis was carried out on rainfall data from Banjarbaru Station for 28 data years. The highest maximum daily rain occurred in 2014 at 214 mm. The lowest maximum daily rain occurred in 2005 at 66 mm.

Table 2. Rainfall design (mm) of Banjarbaru Rainfall Station

P(x >= Xm)	T	Rainfall design (m^{m})							
Probability	**Return Period**	**NORMAL**		**LOG-NORMAL**		**GUMBEL**		**LOG-PEARSON III**	
		X_T	**K_T**	**X_T**	**K_T**	**X_T**	**K_T**	**X_T**	**K_T**
0.9	1.1	63.878	-1.282	72.169	-1.051	70.386	-1.100	**74.576**	**-1.170**
0.5	2.	109.904	0.000	105.135	-0.133	104.004	-0.164	**101.302**	**-0.127**
0.2	5.	140.130	0.842	134.603	0.688	135.742	0.719	**132.205**	**0.780**
0.1	10.	155.929	1.282	153.161	1.204	156.756	1.305	**155.463**	**1.332**
0.05	20.	168.977	1.645	170.400	1.684	176.913	1.866	**179.983**	**1.831**
0.02	50.	183.662	2.054	192.133	2.290	203.004	2.592	**215.287**	**2.441**
0.01	100.	193.452	2.326	208.142	2.735	222.555	3.137	**244.716**	**2.878**

Based on the analysis of the rainfall design data and testing the data with the Chi Square test and the Smirnov Kormogorov test, the design rainfall data was determined using the Log Pearson Type III. Rainfall data for the 100-year return period is 244.716 mm. The design rainfall intensity for the 2 to 100 year return period from 1 hour to 24 hours can be seen in Figure 4.

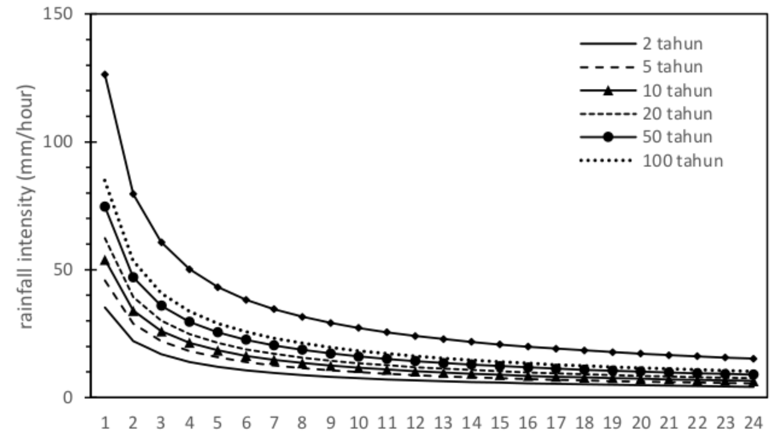

Figure 4. The rainfall intensity graph from 2 to 100 return period

The next analysis is to determine the runoff coefficient from direct observation survey data in several villages in seven districts in Banjar Regency. Landused per village was obtained from primary data, with direct observations in the field. Village area is obtained from secondary data, in Regency data in Figures. Based on the analysis of the runoff coefficient (*C*) in each district from observation, the average design discharge per village from each district is obtained as shown in Figure 5.

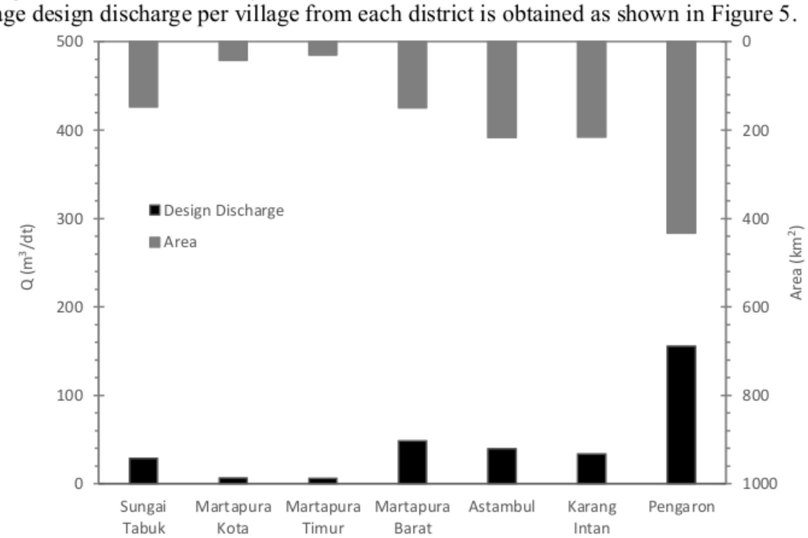

Figure 5. The discharge design per villagein sever district

The design discharge that occurred in the villages in the Pengaron district was the highest due to the relatively high area of impact and the lack of land cover, which was the largest in this location. Analysis was also carried out on data on building rights and property rights for the last 5 years from Banjar Regency data [15]. Data on building rights are presented in Figure 6 and data on the area of rice fields are presented in Figure 7.

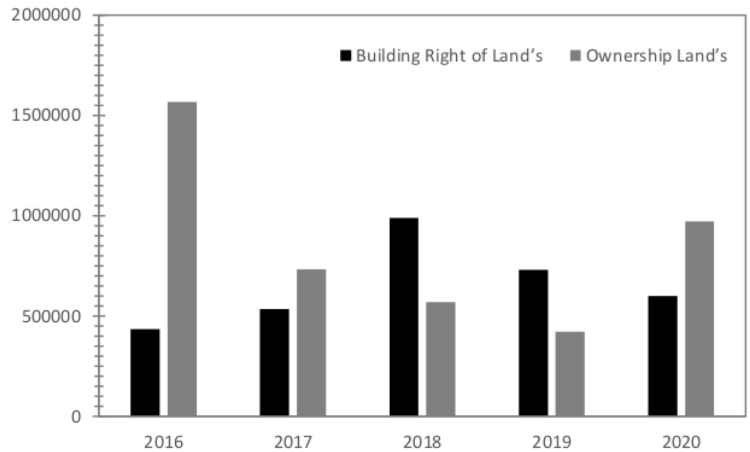

Figure 6. Building Right of Land's and Owneship Land's in Banjar Regency

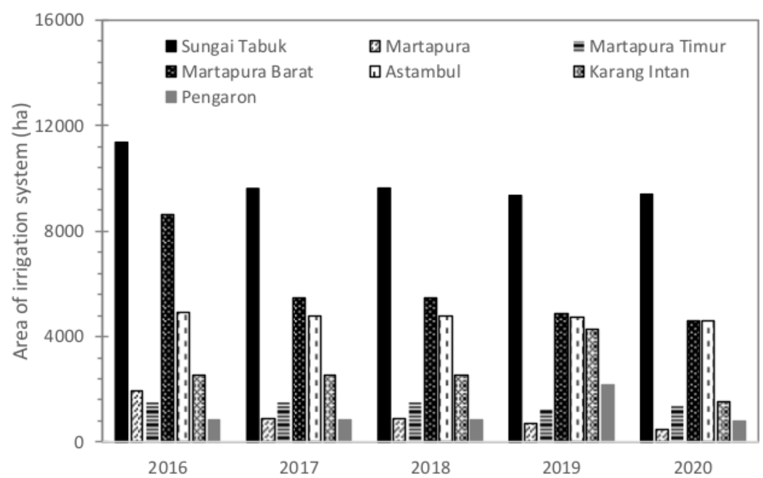

Figure 7. Area of irrigation system (ha) in seven district in Banjar Regency

In Figure 6, it can be seen that from year 2016 to 2020 there was an increase in building right of land's, with the highest land use rights in year 2018 as 98.8674 m^2. The opposite happened to owneship land's where there was the lowest decrease in in year 2019 as 421,211 m^2. The lowest area of paddy fields is in Martapura Kota with an area of 480 m^2 and in Pengaron District with an area of 782 m^2. In Figure 7 during the last 5 years there has been a decrease in irrigated area with a range of 7 to 87%. The largest reduction in rice field area occurred in Martapura Barat District by 87% and Karang Intan District by 68%.

4. Discussion

a. Correlation between hydrometeorological factor and extreme rainfall in 2021
   Berdasarkan analisis data hujan rancangan sebagai faktor hydro-meteorologi dengan series data

Based on the design analysis of rainfall data as a hydro-meteorological factor with a data series of 28 years, the results show that for the 100-year return period, the rainfall design is 244.716 mm. This design rainfall is still under the extreme daily rain that occurred on January 14, 2021. The extreme rainfall recorded at the Banjarbaru Climatology Station was 255.3 mm and at the Syamsudin Noor Meteorological Station of 249 mm. It can be concluded that the very extreme rain that occurred on January 14, 2021 and was evenly distributed in almost all areas in South Kalimantan caused flooding not only in Banjar Regency but also in almost all areas in South Kalimantan.

b. Correlation between anthropogenic factor and internal factor due to flood discharge
The anthropogenic factors caused by human activities such as how they use their house yards are also internal factors in the flood discharge design through the runoff coefficient (*C* coefficient). This data collected from primary data as direct observations in the 68 villages. Based on direct observations of the land use change and land cover in seven districts in Banjar Regency, conclusions can be drawn apart from the extreme rainfall as an internal factor causing flooding, the inability of rainfall to intersept into the ground is also an internal factor that causes flooding to be very high and difficult to seep into the ground. The yard area that is not covered up to 40% which is an atropogenic factor causes the housing area to also be the cause of flooding from internal factors.
One of the anthropogenic factors that have the most impact on any flood event is land-use change. Land-use change causes rainwater that falls cannot infiltrate into the ground. One of the most common community activities is to close the yard and the drains so that rainfall does not have access to penetrate the ground. Second, the conversion of agricultural land and swampland into residential and industrial areas. The third factor that is no less important is the role of the community in development that is not environmentally friendly, one of them by dredging for houses or other buildings. These three anthropogenic factors cause the *C* coefficient of the flow coefficient to increase, and it increases flood discharge.

5. Conclusion

a. The hydrometeorological factor as a natural aspect is depend on on the amount of rainfall that occurs and can not be predicted in the calculation of flood discharge.
b. The anthropogenic factor as an aspect caused by human activities in land use change which are the result of growth patterns in the area. This is greatly affects the value of *C* coefficient and ultimately increases the value of flood discharge.

As the suggestion from this study than citizens in Banjar Regency can be activated to reduce flood disaster based on patterns and behaviors in 1. Planting trees at least 20% of the yard. Trees help absorb water into the soil. 2. Leaving the yard without pavement, leaving the yard open with compacted soil/block with grass will allow water to enter the soil. 3. Keeping the drainage channels around so that they are not clogged by not throwing garbage in the drainage channels, and 4. Leaving waterways. Water will occupy a lower place, so people are advised not to close access to water by backfilling. Take care of WATER then WATER will save our lives.

6. Acknowlegement

This present study was completed by the colaboration of Hydraulic Laboratorium, Engineering Faculty of ULM, Water Resources Development Course Year 2019/2020, and Hibah Pengabdian kepada Masyarakat (PkM) years 2021. This study is one of the outputs of the academic community service in the ULM in the field of disaster mitigation based on the participation of the affected community. This study involves the academic community of lecturers and students in the Water Resources Development course.

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