Temporal Variations of Baseflow Contribution to Epikarst spring Discharge in *Gunungsewu* Karst Area, Indonesia

Muhammad Naufal[1,2*], *Margaretha* Widyastuti[1,2], *Ahmad* Cahyadi[1,2], *Fajri* Ramadhan[2], *Indra Agus* Riyanto[3], *Khansa Sitostratufana Arsy An* nisa[2], *Tjahyo Nugroho* Adji[1,2], *Eko* Haryono[1,2]

[1] Karst Research Group, Faculty of Geography, Gadjah Mada University, Indonesia
[2] Environmental Geography Department, Faculty of Geography, Gadjah Mada University, Indonesia
[3] Program on Planning and Management of Coastal Areas and Watershed, Faculty of Geography, Gadjah Mada University, Indonesia

Abstract. Flow moving slowly (infiltration), and known as steady flow or baseflow is the only supplier of water in underground flows in the form of karst fields during the dry season. Certainly, the character contribution of this flow plays a major role in supporting the supplier of clean water. Understanding related to the character of baseflow in detail has a very high urgency to be studied. This Research aims to do a temporal analysis of baseflow contributions on epikarst water springs in *Gunungsewu* Karst Area, Indonesia. The research takes place in *Guntur* Springs that occupy the hydrogeological subsystem. Data used in this Research includes flow data from *Guntur* Springs for one year. The method used in this Research is automated base flow separation by digital filtering. Results of the analysis show that baseflow contribution in *Guntur* Springs are between 79.57% and 93.96%.

Keywords: **Temporal Variations; Baseflow; Spring Discharge; Gunungsewu Karst Area.**

1 Introduction

Karst is an international term [1] which is used to describe a particular landform [2] in the form of a unique morphology [3] and unique hydrology characteristics as well [4]. The existence of a unique karst environment is formed because of rocks' control that is soluble by water [5] such as carbonate rocks, evaporite and also quartzite. The karst landform is also very similar to the existence of caves and underground hydrogeological systems.

The existence of karst landform has a positive impact on the potential of their resources, including mineral resources, [6] tourism resources, as well as water resources. Pursing on the availability of water resources in the karst, it is known that the water needs of the world population is approximately 20-25% derived from water came from karst [2]. Therefore, the contribution of the character of the water flow to the karst landform plays a major role in supporting the lives of the surrounding communities in certain.

Flow type in aquifers consists of diffuse, fissure, and conduit [7-9]. The diffuse flow is a flow component that fills an underground river that flows through the cavity between the rock grains. This flow component is made up of infiltrated rainwater. Meanwhile, the fissure flow is a flow component that fills the underground river and its flow originates from the gap of carbonate rocks sizing 102-104 mm. This flow is turbulent, especially when there is a flood. The conduit flow is a flow that fills the underground river, with a flow source that it is through a large size dissolving aisle.

Based on the definition of those three flow components, the flow that passes through a cavity between the rock grains which moves slowly is known as diffuse flow [10]. This flow component is the dominant water supplier on the underground river flow in the form of karst landform during the dry season [10, 11]. Thus, it can be seen that this flow component is always present in the dry season and in the rainy season, even though the amount is fluctuating.

In general, Gunungsewu karst is a representation of karst that develops in tropical environments [6] in which the area reaches 3.300 km^2 including province of DIY (some of Gunungkidul District), Central Java (some of Wonogiri), and East Java (some of Pacitan District) (Fig. 1) [9, 12]. The dominance of the Karst land of Gunungsewu uses is in the form of fields (31.56%), and the rest is other land uses [13]. The research takes place in *Guntur* Springs which is part of the Gunungsewu karst located in the west part (hydrogeology subsystem). Administratively, the *Guntur* Springs are included in a Village called Girijati, Purwosari District, Gunungkidul Regency, D.I. Yogyakarta, Indonesia. The area of the *Guntur* Water Spring is 30.7 Ha [14].

This research aims to know temporal variations of diffuse flow on *Guntur* Spring which is epikarst water springs in the area of Gunungsewu karst. This research is expected could give a full description related to the character of diffuse flow on epikarst water springs,

* Corresponding author: naufalmuhammad@mail.ugm.ac.id

especially in a tropical karst area. 4.0 industrial revolution demands everything that takes place in this era of globalization with technological features. Thus, to characterize diffuse flow components, BFI + software is used. This software has a working principle by finding the value of digital filtering on the basis of the recession constant value in the event of a year-long hydrograph. By using this software, processing data with large capacity becomes easier and more effective.

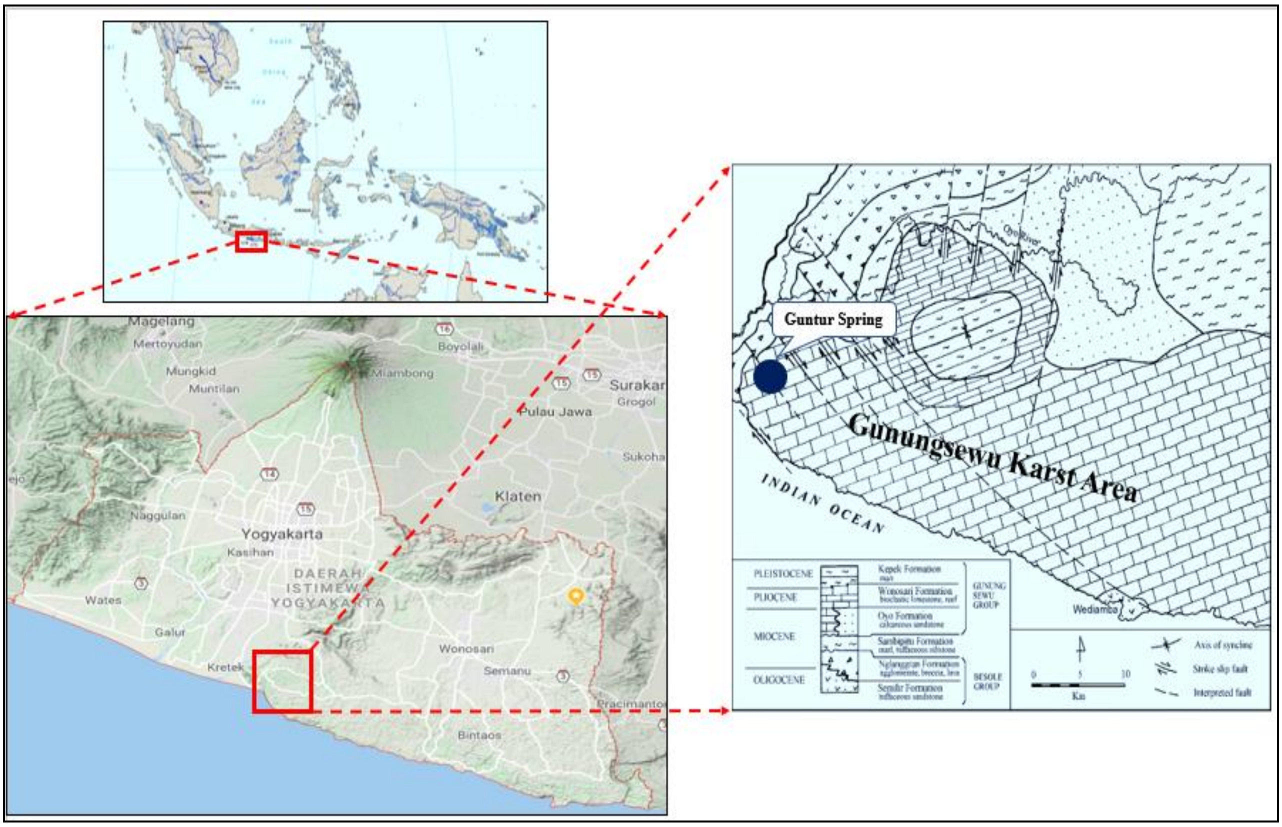

Fig. 1. Research location, *Guntur* Spring as part of Gunungsewu Karst area [15 with modifications]

2 Methodology

Research conducted is experimental research, which is to collect very much data (temporal). Then, it could be analyzed, elaborated with the existing theories, and it is concluded on a particular hypothesis. The main data collected in the research is the data of water level which is recorded through the water level data logger, and they converted to flowrate with a rating curve afterward. Water level data is collected for 1 year, starting in April 2018 until March 2019.

Measurements to represent low, medium and peak flowrate periods are carried out through direct measurements at the field (instantaneous measurement) for 29 times as a basis for making a flowrate curve and rating curve. Thus, it is known the relationship level between water level and flowrate which can be seen in the magnitude of the R value from the correlation results on the curve, and it is also obtained the formula for the relationship between water level and flowrate.

Furthermore, separation of the baseflow can be carried out based on the previously formed hydrograph of the flow. According to [16], he states that the separation of baseflow is a process of separation between baseflow components and the Run Off component. The method of baseflow separation is done by applying an automated method of baseflow separation by digital filtering [17]. The following is a formula of baseflow separation taken from automated baseflow separation by digital filtering.

$$q(bi = \frac{(1-BFImax)\, aqb\,(i-1) + (1-a)BFImaxqi}{1-aBFI\ max} \quad (1)$$

$qb_{(i)}$: Baseflow at time of i
$qb_{(i-1)}$: Baseflow at time of i-1
a : Baseflow Recession constant
BFI_{max} : Maximum baseflow index (0.8 for porous material and perennial stream) [17]

3 Results and Discussion

3.1 Spring Hydrograph

The research conducted at the Guntur Spring is conducted for 1 year starting from April 2018 until the beginning of April 2019. The water level recording device in the Guntur Springs is set with a 10-minute recording interval. The instantaneous flowrate and the water level measurements in the field were carried out

29 times to obtain the equation through making a curve of the relationship between the water level and the flowrate called the rating curve. The following is the table of direct flowrate and water level measurement and also the result of the rating curve in *Guntur* Springs (Table 1 and Fig. 1).

Based on the results of the trend line between the value of water level and the amount of flowrate measured directly in the field, the R value of the rating curve is 0.9724, meaning that the relationship between the two components is closer to 1, that is, both have a strong relationship. The obtained equation is **y=944.62x+24.04**. Based on these equations, the hydrograph of flow from the *Guntur* Water Spring can be presented afterward as follows in Fig. 3, which shows that water always flows from the rainy season to the dry season, even though there are significant flowrate fluctuations between the rainy and dry seasons.

Table 1. Direct Measurement on Water Level and Flowrate in the Fields

No	Measurement		Water level (meter)	Discharge (lit/sec)
	Date	Time		
1	12/05/2018	10.00	0.090	94.44
2	12/06/2018	09.00	0.098	92.24
3	03/08/2018	11.00	0.074	74.82
4	04/09/2018	10.00	0.109	87.16
5	10/10/2018	12.00	0.099	92.24
6	04/11/2018	12.30	0.045	95.46
7	30/11/2018	12.45	0.055	103.09
8	22/12/2018	11.25	0.150	190.24
9	31/12/2018	09.52	0.300	314.33
10	05/01/2019	10.38	0.320	342.45
11	16/01/2019	21.48	0.340	361.86
12	17/01/2019	23.02	0.370	382.70
13	18/01/2019	01.34	0.380	395.00
14	19/01/2019	03.06	0.390	396.63
15	20/01/2019	04.27	0.370	382.69
16	21/01/2019	09.20	0.360	375.80
17	22/01/2019	14.08	0.350	368.92
18	23/01/2019	19.57	0.340	361.86
19	13/02/2019	02.55	0.322	341.80
20	12/02/2019	01.35	0.324	341.80
21	01/03/2019	19.45	0.378	385.19
22	07/03/2019	02.25	0.361	371.06
23	16/03/2019	01.50	0.412	430.44
24	17/03/2010	22.40	0.472	430.62
25	18/03/2019	07.30	0.464	430.44
26	24/03/2019	08.30	0.397	356.58
27	06/04/2019	09.50	0.257	259.26

Sources: Field Measurement (2018-2019)

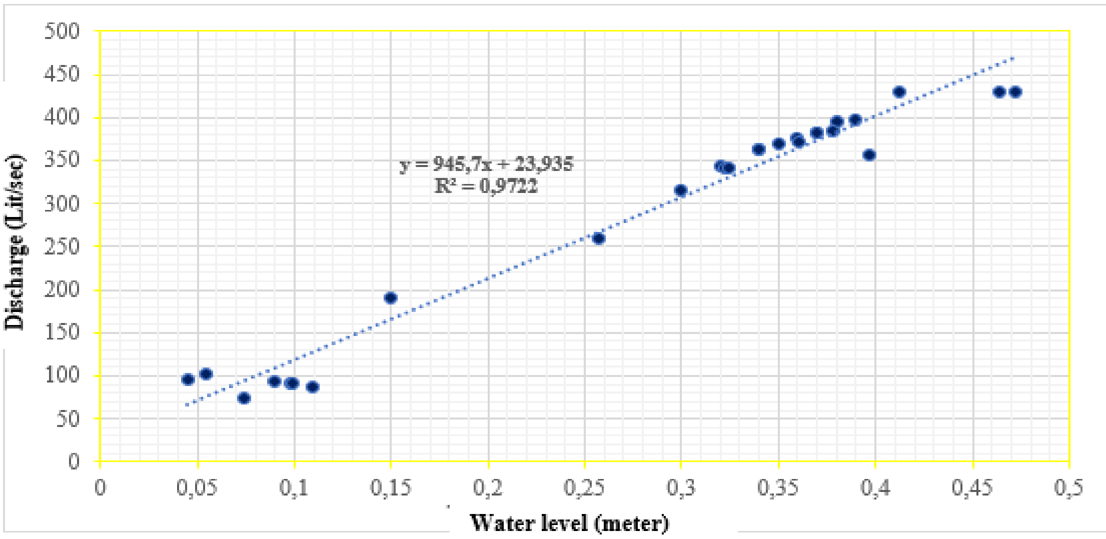

Fig. 2. Rating curve of Guntur Spring

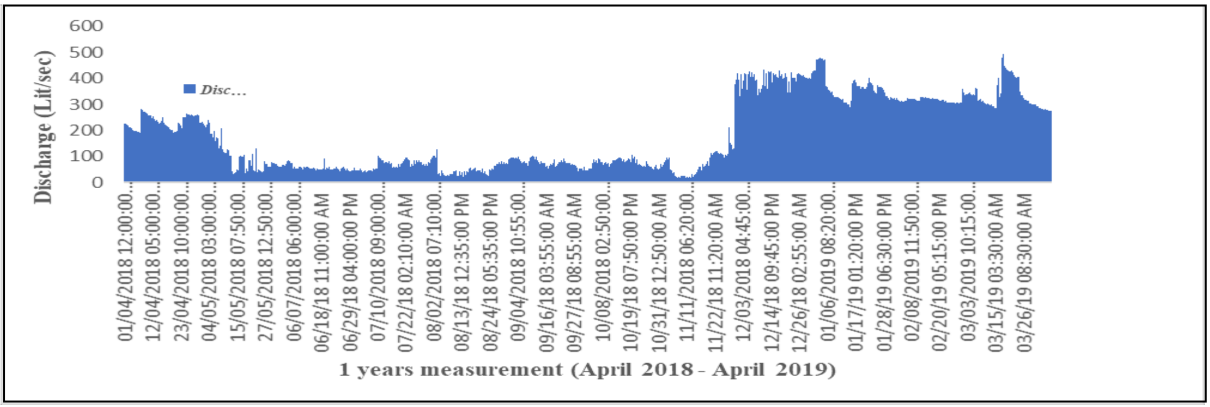

Fig. 3. Hydrograph of Guntur Spring

The appearance of *Guntur* Springs originates from the topographic cutting process caused by the existence of Opak fault [18] and cut north part of Karst Gunungsewu hill afterward [19], one of them is in the hydrogeology subsystem. The lowest and largest flowrate during the research each reached 7.56 lit/sec and 504.23 lit/sec sequentially, with an average of flowrate is 169.14 lit sec. The low amount of flowrate that occurs in the *Guntur* Springs become one of the characteristics of the existence of springs which are in the hydrogeology subsystem at Gunungsewu Karst. The position of the Guntur Springs at the top of the limestone coating makes it one of the causes of the layer above which acts as a thin layer of water storage so that its further impacts on groundwater deposits which are also limited (low) [20]. In line with the statement produced [21], the spring of the hydrogeology subsystem is dominated by Epikarst Springs.

3.2 Baseflow Characteristic of Guntur Spring

Based on the hydrograph of flow that has been produced, 9 selected floods were obtained to identify the baseline characteristics of the *Guntur* Springs. Flood selection is assumed to represent conditions in the early rainy season until the end of the dry season. The following (Table 2) characteristics of the flow in the *Guntur* Springs include the amount of peak flowrate, flood category, flow time to impact (Tp), length of stay (Tb) and also base flow coefficient (Kb).

Table 2. Characteristics of Hydrograph Components based on Selected Flood

No.	Time	Q max (lit/sec)	Flood Category	Tp (Hours)	Tb (Hours)	Kb
1	07/04/2018	279.56	Medium	1.16	205.82	0.990
2	08/05/2018	159.56	Medium	30.16	188.00	0.990
3	22/12/2018	423.56	High	3.60	117.60	0.999
4	23/01/2019	402.56	High	14.50	53.83	0.998
5	18/03/2019	504.23	High	2.16	169.83	0.999
6	24/03/2019	392.56	High	0.50	314.50	0.999
Average				8.68	174.93	0.997

Sources: Data Processing (2019)

The results of data processing (Table 1) through the selected floods to identify characteristics of the flow in Guntur Springs produced an average time needed to reach a peak flowrate of 8.68 hours with the longest time of 30.16 hours and the fastest time for 0.5 hours. This condition is quite relevant to the ongoing flood conditions at that time, that is, when flooding in the low to moderate category, the time needed to reach the peak discharge is longer, and so is the reverse. The length of stay of water (Tb) averages at 174.93 hours, with the longest time in the month when rain and flood occur in the high category, as evidenced by the longest time of 314.50 hours occurring in the flood on March 24, 2019. Furthermore, the recession coefficient at the base of the Guntur Springs is an average of 0.990, meaning that the value shows the slow release of flow components especially the baseflow in the Guntur Springs. Moreover, all these conditions reflect that the flow component in Guntur Springs is supported by a diffuse flow system that is quite dominating. Thus, it can be concluded, that during the dry season, the Guntur Springs continue to flow even though in low flowrate, which originates from the baseflow with slow release characteristics and the flow system is still in the form of seepage. The results of one-year baseflow separation processing are presented as follows (Fig. 4 and Table 3).

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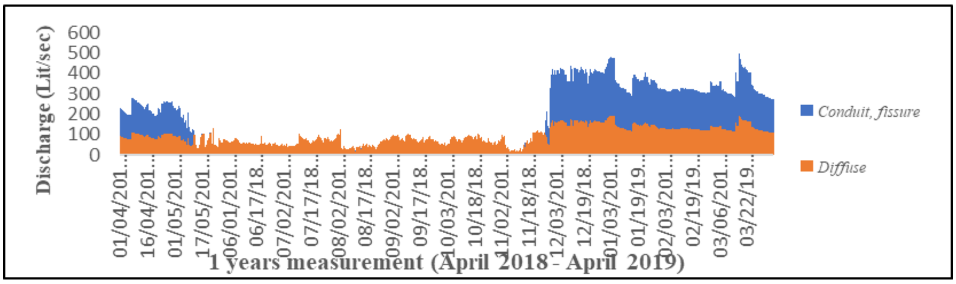

Fig. 4. Baseflow separation of *Guntur* Spring

Table 3. Monthly Baseflow Characteristic

No.	Month	Average of discharge (lit/sec)	Average baseflow (lit/sec)	Average of baseflow proportion (%)	Season
1	April '18	230.61	184.11	80.03	Initial of dry season
2	May '18	107.94	89.43	80.03	Mid of dry season
3	June '18	70.55	56.35	80.03	Mid of dry season
4	July '18	76.50	57.80	80.03	Mid of dry season
5	August '18	51.67	41.31	100	Mid of dry season
6	September '18	74.43	59.99	100	Late of dry season
7	October '18	70.55	56.35	100	Late of dry season
8	November '18	76.50	57.80	100	Initial of rainy season
9	December '18	366.26	290.07	79.57	Initial of rainy season
10	January '19	351.07	282.40	79.58	Initial of rainy season
11	February '19	311.82	249.76	79.59	Mid of rainy season
12	March '19	336.41	270.15	80.60	Mid of rainy season
13	April '19	277.72	224.27	80.59	Late of rainy season
Average				93.33	

Sources: Data Processing (2019)

Fig. 4 shows the proportional magnitude of the baseflow over 1 year. Further in table 3 presents the monthly mean baseflow that occurs with the average of baseflow proportion each month. How long the range average of baseflow that occurs starts from 41.31-290.07 lit/sec. Based on the results of data processing, the basic value of the baseflow is dominantly greater in the month which is included in the rainy to the late rainy season than in the dry season. This condition certainly occurs because springs are likely to be more massive in getting water supply during the rainy season, different from conditions in the dry season.

The average proportion of baseflow per month, the month classified as the dominant dry season has a greater proportion than in the rainy season (May-August 2018). This condition certainly occurs because the flow is more dominant in the dry season even the whole consists of only components of the base flow proportion, without any contribution of the direct flow (conduit). While, it is different when the rainy season takes place, the proportion of the baseflow will certainly be lower because of the contribution of the direct flow component. Thus, the proportion of baseflow becomes larger in the dry season than the baseflow proportion in the rainy season. As for supporting this statement, it can further be understood through the separation of the baseflow from selected floods in 1 year as follows (Table 4 and Fig. 5).

Table 4. Baseflow Separation of Selected Flood Events

No.	Selected flood event	Peak discharge (lit/sec)	Flood category	Baseflow (lit/sec)	Baseflow proportion (%)
1	07/04/2018	279.56	Low	224.65	80.36
2	08/05/2018	159.56	Low	128.45	80.50
3	22/12/2018	423.56	High	338.05	79.81
4	23/01/2019	402.56	High	321.25	79.80
5	18/03/2019	504.23	High	370.88	73.55
6	24/03/2019	392.56	High	313.25	79.79
Average					78.97

Sources: Data Processing (2019)

The baseflow events that occur range from 50.05-370.88 lit/sec. The existence of a fairly large range of values between the baseflow in the selected flood March 17, 2019, and the others is because there is a savanna cyclone that occurs and impacts the emergence of rain with a long intensity and with sufficiently high rainfall at that time, resulting significant increase in water level and further on the abundance of the baseflow. The proportion of the baseflow, almost the same as the average monthly yield, in selected floods the dominance of the proportion of baseflow is greater in the dry season, which in table 4 is classified with the category of moderate to low flooding.

Baseflow contributions, as discussed earlier, have a greater proportion in the dry season than during the rainy season. Figure 5 represents a block diagram of baseflow separation at each flood event. During the rainy season, the direct flow has a greater contribution so that it reduces the proportion of the basic flow component. Shown from the left to the right diagrams, which proves that the more the right of the block diagram, the flow of baseflow proportions decreases and the proportion of the direct flow (conduit) increases. The most significant decrease in baseflow contribution with the largest direct flow contribution can be seen in the selected flood diagram block that occurred on the 17th March 2019 when the cyclone savanna occurred.

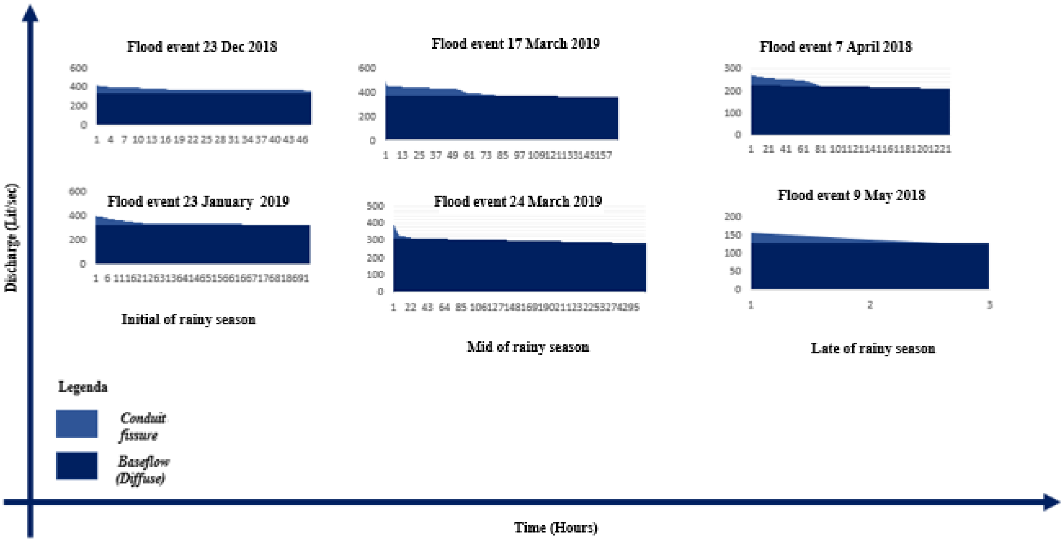

Fig. 5. Selected Flood Graphic of Baseflow Separation Event

4 Conclusion

The lowest and largest flowrate during the research each reached 7.56 lit/sec and 504.23 lit/sec, with an average flowrate of 169.14 lit/sec. The low amount of flowrate that occurs in the Guntur Springs is one of the characteristics of the emergence of springs which are in the hydrogeology subsystem at Gunungsewu Karst. The average time needed to reach the peak discharge for 8.68 hours with the longest time of 30.16 hours and the fastest time for 0.5 hour. This condition is quite relevant to the ongoing flood conditions at that time, that is, when flooding is in the low to moderate category, the time needed to reach the peak flowrate is longer, and so is the reverse. The length of stay of water (Tb) averages at 174.93 hours, with the longest time in the month when rain and flood occur in the high category, as evidenced by the longest time of 314.50 hours occurring in the flood on March 24, 2019. Furthermore, the recession coefficient at the base of the Guntur Springs is an average of 0.997, meaning that the value shows the slow release of flow components especially the baseflow in Guntur Springs. Furthermore, all these conditions reflect that the flow component in the Guntur Springs is supported by a diffuse flow system that is quite dominating.

Baseflow event range that occurs starts from 41.31 – 290.07 lit/sec. Based on the results of data processing, the basic value of the baseflow is dominantly greater occurring in the month which is included in the rainy to a late rainy season than in the dry season. This condition certainly occurs because springs are likely to be more massive in getting water supply during the rainy season, different from conditions in the dry season.

During the rainy season, the direct flow has a greater contribution so that it reduces the proportion of the baseflow component. Shown from the left to the right diagrams, which prove that more to right side of the block diagram, the flow of the baseflow proportions decreases, and the proportion of the flow conduit increases. The most significant decrease in baseflow contribution with the greatest direct flow contribution can be seen in the selected flood diagram block that occurred on March 18, 2019, when the cyclone savanna occurred. Results analysis to show that contribution diffuse flow at Guntur Springs is between 79.57% and up with 100%.

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