

RESEARCH ARTICLE

Geomorphological Assessment to Tract the Flow Evolution of Kali Putih, Srumbung District, Magelang Regency, Central Java, Indonesia

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Received: Nov 17, 2019. Accepted: March 13, 2020.

DOI: 10.25299/jgeet.2020.5.1.4096

Abstract

Kali Putih (The White River) is located in Srumbung district, Magelang regency, Central Java, Indonesia. It is originated from the upper slope of Merapi volcano, flowing to the Southwest direction. Kali Putih belongs to one of the most channels where frequently flowed by lahar of Merapi volcano. Based on geomorphological and geological traces found at the surrounding of modern Kali Putih channel, this indicated that the flow of Kali Putih has undergone displacement several times. The position of ancient river valley in the past has changed into the modern river valley in the present time. The existence of ancient Kali Putih is exhibited by the presence of large dry valley morphology associated with volcanic blocks, gravels, and sand sized materials with various sorting, representing the characteristics of lahar and alluvial deposits. In the present time, the former river channels are currently used by local people for agricultural and fisheries land. This research was conducted in order to analyse and determine the evolution of the ancient Kali Putih valleys, and the current river that acting as a collecting channel of lahars and pyroclastic avalanches of Merapi volcano. By concerning to geological law of "the present is the key to the past", results of this research can be used as a reference for studies related to volcanic disaster mitigation of the surrounding area.

Keywords: Kali Putih, flow evolution, geomorphology, lahar

1. Introduction

One of some volcanic products generated by such an active volcano is lahar, that belongs to the strongest erosion forces, destructive, and capable of creating disaster. Besides its high capacity of erosion and sedimentation, lahar flows also generally create a strong impact to the environment (Lavigne, et.al, 2000). Material deposits that exceed the capacity of such a river to hold, will bring environmental problems to downstream. Problems caused by lahar sedimentation can be in the form of the closure of irrigation channels, siltation of the riverbed, and the buried of land around the river channel due to overflow of lahar which is not able to be accommodated by the river. Changes in flow of the river's morphology caused by lahar include widening of the river channel, streamlining of the river flow, and silting of the riverbed (Murwanto, et.al, 2013).

In the research area, there is a river, namely Kali Putih (the White River) which often used by lahar as the secondary product of Merapi volcano eruption to flow (Murwanto, et.al, 2013). The river is located in Srumbung District, Magelang Regency, Central Java Province, Indonesia (Fig. 1), that belongs to an area with dense population. The local community mostly live in the adjacent of river flow, while the river itself is used to be threatened by lahar.

Based on remote sensing analysis using Earth's map and Google Earth imagery, there are found straightness of river paths which interpreted as the former of Kali Putih flows. This indicates that Kali Putih has ever changed its flow due to natural processes. In order to derive geohistorical data and information on Kali Putih and lahar disaster in the past time, then the evolution of Kali Putih flow is needed to be traced with scientific assessment in the form of geomorphological and geological studies.

This study aims to determine the evolution of the ancient Kali Putih valleys, and the current river that acting as a collecting channel of loose material, lahars or volcanic mud flows, and pyroclastic avalanches of the Merapi volcano.

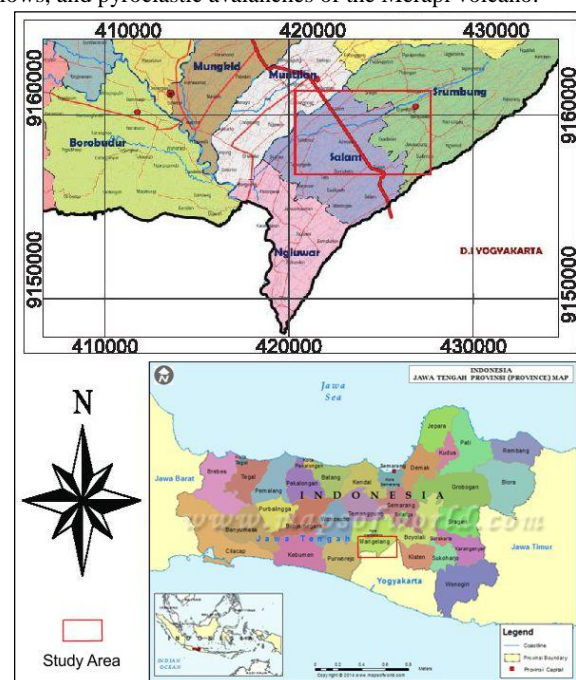


Fig. 1. Location map of the Research area

2. Methods of the Study

Method carried out in this study is descriptive, and analytic, combining with assessment on Merapi volcanic

history and field observation by conducting geological and geomorphological mapping. Data to be assessed including secondary and primary data. The secondary data were satellite imageries, *Peta Rupa Bumi Indonesia* (Indonesian map of earth appearance) and regional geological map of Merapi volcano, while primary data in terms of geomorphological and lithological characteristics were derived from field survey and mapping.

Field survey and mapping activities done in this research can be divided into several stages, including data acquisition, literature review, analyses on flow patterns, geomorphology, stratigraphy, geological structure, and petrology, and synthesis related to identification of the evolution of Kali Putih flows.

3. Results and Discussion

3.1 Geomorphology

In the present time Kali Putih flow is situated on the southwestern slope of Merapi volcano. Places flown by Kali Putih are Cabe Kidul, Ngaglik, Remame, Jumoyo Kidul, Pendem, Seloboro, Tersangede, Baturono. There are some ancient valleys that interpreted as the former Kali Putih flows. The first valleys found in Srumbung Kidul, Kemiren, Jumoyo Lor, Pulosari, Pendem, Seloboro, and Gajahan. The second valleys discovered in Srumbung, Gempol, and Seloboro. The valley of modern Kali Putih itself is situated in Srumbung area, Jumoyo, and Seloboro.

In order to study the evolution of Kali Putih flow, the geomorphology of the surrounding area needs to be analysed. However, landform has an important role to control erosion and flow of surface water. Referring to Setyawati & Ashari (2017), the Srumbung district is situated on the southwestern

slope of Merapi volcano, the landforms can be divided into volcanic food slope, volcanic footplain, and isolated hills (Fig. 2).

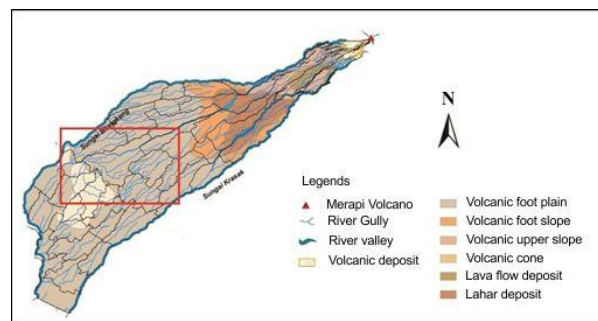


Fig. 2. Geomorphologic map of the southwestern slope of Merapi volcano (Setyawati & Ashari, 2017). Red box shows situation of the research area.

Field observation on the ancient Kali Putih channels was carried out to determine the position of the previous Kali Putih flow. This observation is related to geomorphology that consisting of assessment on morphology, morphometry (valley shape, valley width and valley length), passive morphostructure (lithology), and morpho-association. Based on this study, the geomorphology of the research area can be divided into for geomorphic units, namely volcano footslope unit, river channel unit, isolated hill unit, and isolated ranges unit. Geomorphological map of the research area is displayed in Fig.3.

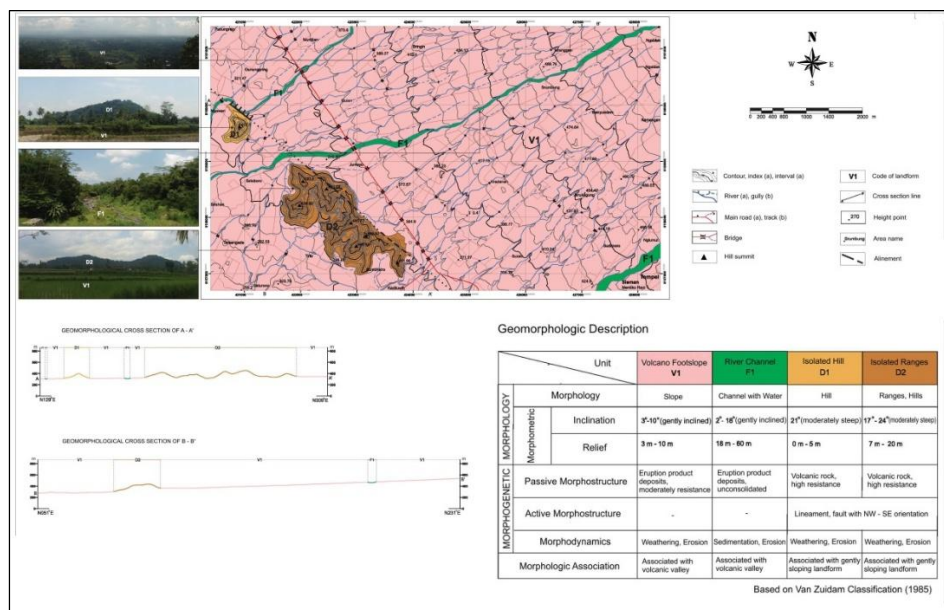


Fig 3. Geomorphological Map of the Research area

3.2 Geology

Mainly, geology of the research area is influenced by Merapi volcano activities. Product of the volcanic actions can be in the forms of primary yield as pyroclastics, and secondary creation as lahar. There are two kinds of Merapi volcano pyroclastics, called fall pyroclastics, and flow or avalanche pyroclastics (Kusumayudha, 2017). Lahar is a debris and mud concentration formed from a mixture of water, particles, sand, and boulders (Paripurno, 2009). The source of water can be rainfall, crater lakes, or melting of ice, while the particles come

from pre-existing pyroclastic avalanches as well as material produced directly from eruptions.

Primary Lahar occurs in volcanoes that there is a crater lakes. The base of its crater is impermeable so that a number of rainwater will be collected inside. If the volume of water in the crater is large enough, when an eruption occurs it can spill hot mud with temperatures reaching above 100°C (Lavigne, et.al, 2000).

Rainy lahar (secondary lahar) or better known as cold lahar occurs when volcanic materials that have not been consolidated on peaks and slopes, at or after the eruption, then

mixed with rainwater. These pyroclastic materials will be transported and move downward as a high density of flow. (Lavigne, et.al, 2000).

Lahar belongs to one of the strongest erosion forces. Sedimentation by lahar flows that exceed the river's boundary limits generally brings environmental problems downstream, such as siltation of the riverbed, closure of irrigation channels, and buried of land around the river channel. It is due to the overflow of material lahar that can not be accommodated by the river passage. Environmental changes due to lahar overflows include transformations in river flow morphology, such as channels widening, basins streamlining and siltation, and sedimentation characteristics changing (Thouret, et.al, 2000).

Lahar flow velocity is influenced by slope inclination, rainfall intensity, and material volume. The steeper the slope, the speed of the lahar flow will increase (Thouret, et.al,

2000). Genetically lahar is divided into two types, namely lahar of eruption (primary) and lahar of rainfall (secondary).

Based on characteristics of the dominant lithology, and referring to the regional stratigraphy according to Wirakusumah, et al. (1989) and Paripurno (2009), the rock units in the research area are determined as composed of Gendol lava units, Merapi lahar deposit 1 units, Merapi lahar deposit 2 units and alluvial deposits.

Referring to Wirakusumah, et al. (1989) and Camus et.al. (2000), the Gendol lava unit belongs to the oldest old rock group in Srumbung area, it is Tertiary geological age. The stratigraphic relationship between Gendol lava units and Merapi lahar deposit 1 unit is nonconformity. The stratigraphic relationship between the Merapi lahar deposit 1 unit and the Merapi lahar deposit 2 unit is aligned. The geologic map of the research area is shown in Fig. 4.

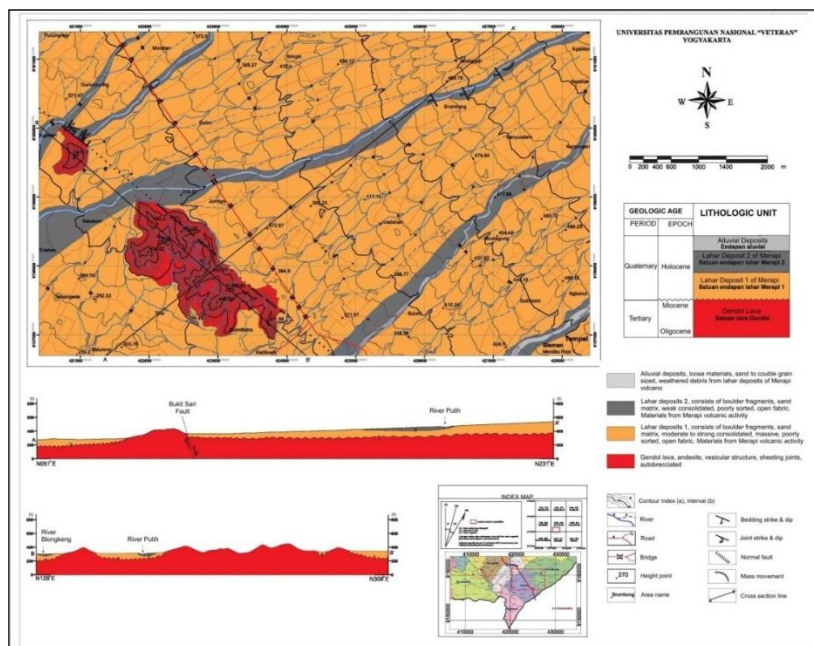


Fig 4. Geological map of Kali Putih and surrounding area

3.3 Merapi Activity History

Before the year 1994, say 1960(s), 1930(s), 1900(s) etc eruptions of Merapi volcano generally toward southwestern direction (Kusumadinata, 1979). Characteristics of the eruptions were variation of volcanian, pelean, and merapian types (Kusumayudha, et.al, 2019). All of the types of eruption generally produced pyroclastics that deposited on the western flank of the volcano. When the deposits mixed with rain water to become more dense and heavy, then flowed downward lead by gravity, forming lahar (Kusumayudha, 2017). Because of this situation, the research area always passed by pyroclastic and lahar flows of that times. Due to its role as the area of where always flown by lahar and pyroclastic, subsequently this area lithologically composed of pyroclastic and lahar deposits.

Kali Putih is one of the rivers that flows to the southwest of Mount Merapi. The river is frequently affected by rain lahar flows. Based on the historical records, this river had been fed by lahar on November 21-25 1975, March 6, 1976, November 20-27, January 1993, July 1998 (Lavigne, et.al, 2000), and in the end of 2010 to 2011 (Kusumayudha, et.al, 2019).

The potential of lahar flow in the Kali Putih is still quite large. It is supported by the fact that there are still many materials in the upper slope, as well as the high potential for rainfall. This huge potential is a serious threat to changes the morphology of Kali Putih channel. By referring to "the present

is the key to the past", it can be strongly presumed that Kali Putih has undergone such a flow evolution.

There has been some ancient Kali Putih grooves, indicated by the presence of a wide valley morphology with lahar deposits in the form of andesite blocks. The existence of a large valley and the presence of lahar deposits prove that the area was once a river channel that had been flowed by lahar. Ancient Kali Putih grooves can be found in the Srumbung area to Salam. Some of the former areas of the Kali Putih channel are used by the community as agricultural and fisheries land.

As has been mentioned above, the existence of ancient Kali Putih in the research area can be observed based on geological and geomorphological aspects, including morphometric, morphogenesis, and morpho-association. Results of the assessment pointed that Kali Putih was subjected to flow displacement three times.

3.3.1 Kali Putih Evolution

a. Ancient Kali Putih 1

The ancient Kali Putih 1 is found in the areas of Cabe Kidul, Ngaglik, Babadan, Remame, South Jumoyo, Pendem, Seloboro, Tersangede and Baturono. The upper reaches of the river is in the Northeast of Lombok Kidul (Fig.5.). The geomorphological aspects are as follows:

Table 1. geomorphological aspects Kali Putih 1

Morphography	Longitudinal valley, river terraces with flow direction from northeast to southwest, dammed by Gendol Hills, afterward turn around the hills, and then turn back to flow to relatively southwestward direction (Fig. 5, Fig.6.).
Morphometry	a. valley shape: "U" b. valley width: 30-60 meter
Active Morphostructure	Lahar deposits and alluvial deposits (Fig.7.).
Morphographic Association	Volcanic food slope, volcanic food plain, isolated hills



Fig 5. Ancient Kali Putih 1. Dash lines show the old channel of ancient Kali Putih 1 (Photo Source: Google Earth).



Fig 6. Old channel of ancient Kali Putih 1.



Fig 7. Old lahar deposit on the ancient Kali Putih 1 river bank.

b. Ancient Kali Putih 2

Ancient Kali Putih 2 is found at villages of Srumbung Kidul, Jamblang, Kemiren, Jumoyo Lor, Pulosari, Pendem, Seloboro

and Gajahan (Fig. 8). The geomorphological aspects are as the following:

Table 2. geomorphological aspects kali putih 2

Morphography	Longitudinal valley, river terraces with flow direction from northeast to southwest, dammed by Gendol Hills, afterward turn around the hills, and then turn back to flow to relatively southwestward direction (Fig. 8, Fig.9.).
Morphometry	a. valley shape: "U" b. valley width: 30-92 meter
Active Morphostructure	Lahar deposits and alluvial deposits (Fig.10.).
Morphographic Association	Volcanic food slope, volcanic food plain, isolated hills

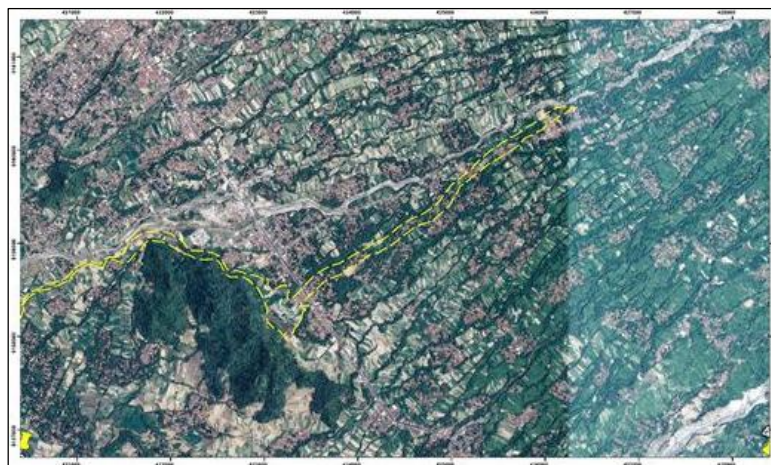


Fig 8. Ancient Kali Putih 2. Dash lines show the old channel of ancient Kali Putih 2 (Photo Source: Google Earth).



Fig 9. Old channel of ancient Kali Putih 2 at Gajahan village

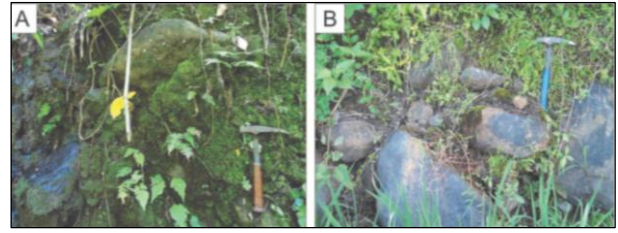


Fig 10. Old lahar deposits on the river bank of ancient Kali Putih 2 at Pendem village (A); at Gajahan village (B).

c. Ancient Kali Putih 3

Ancient Kali Putih 3 is discovered in Gempol village (Fig. 11.). The geomorphological aspects are as the following:

Table 3. geomorphological aspects kali putih 3

Morphography	Longitudinal valley and river banks with flow direction relatively northeast – southwest without colliding Gendol Hills (Fig. 11, Fig. 12.).
Morphometry	a. valley shape: “U” b. valley width: 26-78 meter
Active Morphostructure	Lahar deposits and alluvial deposits (Fig. 13.).
Morphographic Association	Volcanic food slope, volcanic food plain

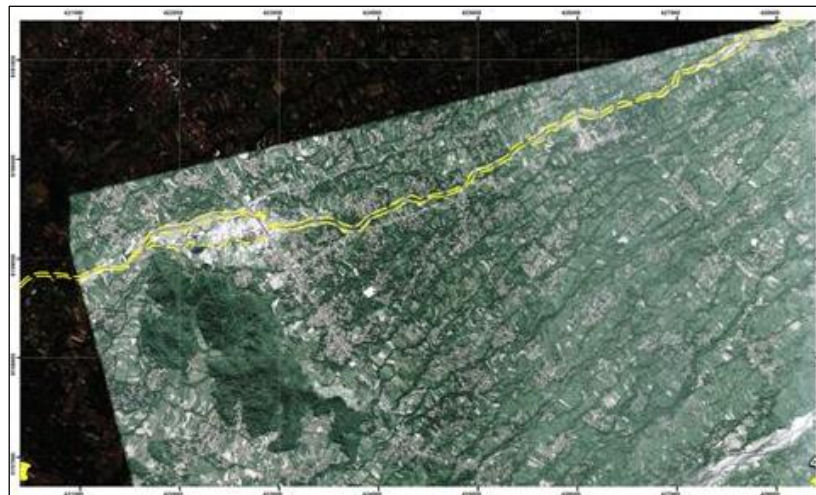


Fig. 11. Ancient Kali Putih 3. Dash lines show the old channel of ancient Kali Putih 3 (Photo Source: Google Earth).



Fig. 12. Ancient Kali Putih 3 at Gempol village.



Fig. 13. Old lahar deposits on the ancient Kali Putih 3 river bank at Gempol village.

d. Modern Kali Putih

Modern Kali Putih can be found at Salam, Jumoyo, and Srumbung areas (Fig. 14.). The geomorphological aspects are as the following:

Table 4. geomorphological aspects Modern Kali Putih

Morphography	Longitudinal valley of northeast – southwest direction (Fig. 14, Fig. 15.).
Morphometry	a. valley shape: “U” b. valley width: 30-60 meter
Active Morphostructure	Lahar deposit and alluvial deposit (Fig.16.).
Morphographic Association	Volcanic food slope, volcanic food plain



Fig14. Modern Kali Putih. Dash line shows the old channel of modern Kali Putih (Source: Google Earth).



Fig 15. Modern Kali Putih channel at Pondok area (A); at Karangowang area (B).



Fig 16. Lahar and pyroclastics (flow pyroclastic, glowing cloud) deposits on the river bank of modern Kali Putih at Pondok area.

Based on the above analysis, it can be concluded that Kali Putih has undergone three times flow displacement, which started from the ancient Kali Putih 1, the ancient Kali Putih 2, the ancient Kali Putih 3, and become the modern Kali Putih. The displacement was due to the damming of the river channel

by volcanic materials so that the river water required a way out and formed a new river channel.

The results of this study are a map of the evolution of Kali Putih in Srumbung Subdistrict, Magelang Regency, Central Java Province which can be seen in Fig.17.

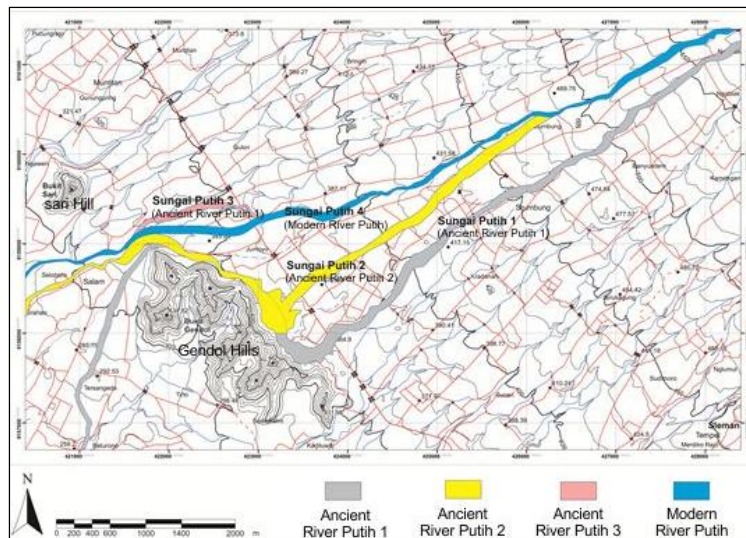


Fig. 17. Evolution map of the Kali Putih in Srumbung Subdistrict, Magelang District, Central Java.

The evidence of changes in river flow, the discovery of volcanic material, and the existence of river terraces reinforce the hypothesis on Kali Putih channel evolution. Some information from local communities also further strengthens this hypothesis. The ancient Kali Putih 1 was estimated to be before 732 AD, as evidenced by the presence of the Canggal Inscription on Wukir Hill of 732 AD (Murwanto, et al, 2013).

Ancient Kali Putih 2 is a subversion of the ancient Kali Putih 1 flow caused by the damming of the river by volcanic material so that the river water looks for a way out by creating the flow of the ancient Kali Putih 2. According to Murwanto, et al. (2013), the ancient Kali Putih 3 in the Gempol area was the previous Kali Putih which was moved by the Dutch Colonial

Government to facilitate the construction of Magelang-Yogyakarta connecting road.

Nowadays the ancient Kali Putih channels are used by the local people for farming and fisheries, while the modern Kali Putih flow is still potential of hit by lahars in the future. Due to the dense population of the surrounding area, in order for disaster mitigation, it is necessary to make serious efforts so that the river banks are not used as settlements. Some embankments are need to be built along the riverbanks, and also need to pay attention to bridge constructions that pass through the river often flow by lahar.

4. Conclusions

Based on the results of geological and geomorphological analyses by using RBI map and Google Earth's images in this study, some conclusions can be summarized, as the following:

1. The geology and geomorphology of Srumbung Area are strongly influenced by Merapi volcano activities and eruption products, such as pyroclastics and especially lahars.
2. There is a river, called Kali Putih that its origin is from the upper part of Merapi volcano. Based on the historical records, Kali Putih that flows to the southwest, frequently affected by lahar flows.
3. Kali Putih flow in Srumbung area has undergone three times flow displacement, which started from the ancient Kali Putih 1, the ancient Kali Putih 2, the ancient Kali Putih 3, and become the modern Kali Putih.
4. The displacement of Kali Putih channel was due to the damming of the river channel by volcanic materials so that the river water required a way out and formed a new river channel.
5. For disaster mitigation, the river banks are suggested not to be used as settlements. Embankments need to be built along the riverbanks, and bridges that pass through the river often flow by lahar need such a special construction.

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