Management Risk of Overflow Underground River in Karst Gunung Sewu, Gunung Kidul, Yogyakarta

by Barlian Dwinagara

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ABSTRACT

One of the dangers that can arise in the karst area is the overflow of underground rivers. The Karst region is mostly composed of limestone which is soluble in water. Underground river flows may occur when impermeable layers are blocking the flow of water infiltration from surface through the weak zone such as fractures. One of the existing underground river systems in the Wonosari Karts area is the Bribin-Baron underground river which is one of the main river systems in the Karst Gunung Sewu region. The underground river system is similar to the U pipe system where as the water volume exceeds the capacity of the river, the flow of water can appear to the surface through one of its holes. In this study using literature and secondary data collection which then conducted field checking. Then we do the assessment and evaluation of data obtained and make recommendations on risk management in this area. From the analysis obtained there are several factors that can trigger underground river floods such as rainfall, morphology, geological structure. The results of the assessment and evaluation found that the good management of disaster risk overflow underground river in Karst Wonosari region is required in this area. Such as to estimate the areas that could potentially become an underground river burst. From this research is expected to contribute in disaster mitigation efforts in karst area.

Keywords : Hydrogeoloyi, Karst, Sungai Bribin

INTRODUCTION

Gunung Kidul, Yogyakarta is located on karst landscape, known as Gunung Sewu karst hills. There are many karst phenomenon that can be found in Gunung Sewu hills, one of those phenomenon is underground river. Bribin River is one of the underground rivers in Gunug Sewu Karst area. Sungai Bribin has many benefits for Gunung Kidul communities, especially for clean water needs and agriculture. On 28th November, 2017 Bribin underground river flooded. This underground river overflow causes a large volume of standing water. There were recorded several puddles due to the overflow of the Bribin River. Overflow mostly occurs in karst windows areas such as caves which are one stream with Bribin River and has negative morphology. One of the locations is Ngreneng Cave as a one-stream karst cave with Bribin River.

Based on information from the communities around Ngreneng Cave, a puddle of water appears reaching a dozen meters and covers an area of about 25 hectares of land until it looks like a lake. Therefore, they named the lake as "Lake Tiban" which means that lake fell from the sky.

Although the phenomenon of lake formation is temporary and infrequent, it still has a high risk and can be detrimental. Even most or almost all the surrounding communities do not know how the event can occur and what must be done and prepared if the event is repeated. The objective of this study is to analyze and identify the phenomenon of Bribin's underground river in order to manage the risk of the event therefore it does not cause harm to the surrounding community.

STUDY AREA

The study are located onSemanu District, Gunung Kidul Regency, Special Region of Yogyakarta Province. It is lies on the south, contains by carbonate rocks. Carbonate rocks that on this area are thick enough to form karst morphology with land forms such as karts hills. This research was carried out in three caves namely Ngreneng Cave, Bribin Cave, and Sindon / Bribin II Cave. Where the four caves occurred, there were overflows of water from the same underground river.

Figure 1 Study Area, Source : Google Earth 2018

METHODOLOGY

This research method uses primary and secondary data collection. The research method begins with secondary data collection were conducted to obtain pre-liminary data which could be the basis for explaining how underground rivers in karts areas could overflow. Then we take the primary data from observation field. This observation field do to get the coordinate of each caves, geomorphological data, and the relation of each caves. Secondary data include:

1. Geological data on study area : lithology, stratigraphy, and geological structure.
2. Geomorphological data : topography, landform, drainage pattern, distribution of karst caves, and Bribin River flow map.
3. Climatological data : rainfall, hydrology, and climate data.

Furthermore, the combination of these two data is analyzed and become the basis for preparing the assessment of observation locations where the river overflows. This assessment will be used as a basis in managing the risk of river overflows danger under the Bribin river.

GOLOGICAL ASPECT

Lithology

Lithology on the study area are mostly carbonate rocks which are part of the Wonosari Formation. Stratigraphically, Wonosari Formation is included in Southern Mountains Zones. Wonosari Formation is composed by layered limestones, massive limestones, and reef limestones (Kusumayudha, 2004). Wonosari Formation has a specific characteristic, namely the presence of secondary porosity in the form of cavities formed due to the dissolution of calcite and dolomite minerals (Kusumayudha, 2004).

Research areas are included in the Southern Mountains Zone of eastern Java. Where the geological structure developed in the form of faults and muscular faults trending northeastern southwest and northwest-southeast (Prasetyadi et al., 2011). The geological structure that develops becomes the main controller for the formation of karst morphology in the study area.

Geological structures developed in study area area are faults and fractures oriented to northeast (NE) – southwest (SW) and northwest (NW) – southeast (SE) (Prasetyadi et al., 2011). These geological structure develope and becomes the main controller for the formation of karst phenomenon in the study area.

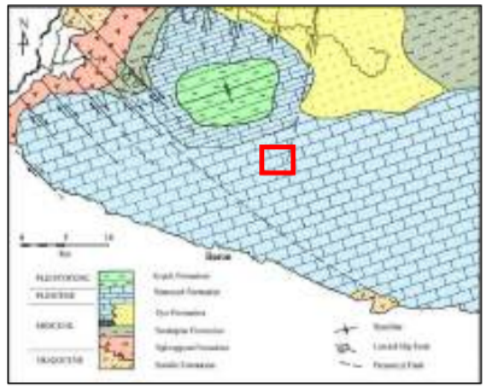

Figure 2 Geological Map of Gunung Sewu, Gunung Kidul (Kusumayudha et al., 2015)

Geomorphology

The forming process of morphology and landform in karst is called karstification. Karst morphology is divided into exokarst and endokarst. Eksokarst is a karst morphology found on surfaces such as karst hills,dDolina, uvale, and polje. Whereas endokarst is karst morphology that are beneath the surface such as karst caves and underground rivers. On the study area, this process is strongly influenced by the stratigraphy, geological structure, and surface processes such as erosion and dissolution. Faults and fractures will become weak zones in the rock and cause greater solubility on carbonate rock. The high level of solubility in carbonate rocks will cause porous rocks and easily eroded. This process causes morphology such as dolena, uvala, shinkhole, and underground rivers.

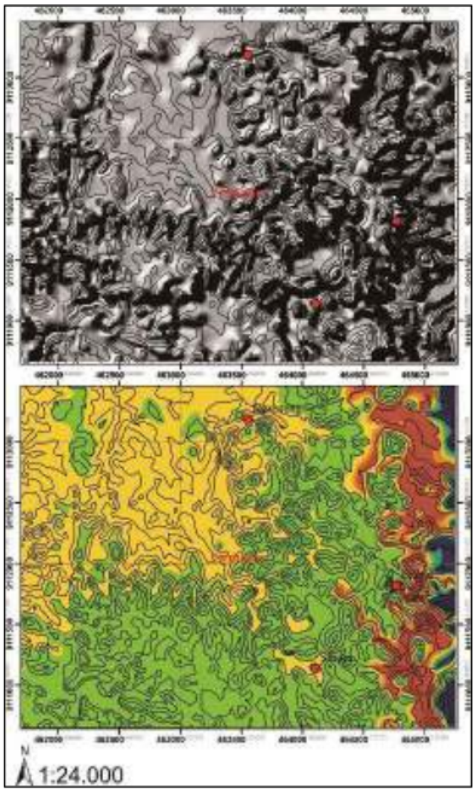

Figure 3 Topography map and Distribution karst morphology

Hydroheology

Hydrological system in the study area is karst hydrological system. Where the karst hydrology system is highly controlled by dissolution process which is strongly influenced by secondary porosity in the form of a pipe. This pipe can be integrated into a cavity which then becomes a channel. Therefore, the system that develops in karst hydrology is rarely in the form of a surface river. However it is in the form of a dissolved tunnel such as underground rivers and caves. In karst hydrology system, secondary porosity become an important factor more than primary porosity in the rock. According to Kusumayudha (2004), the circulation of water in the karst aquifer is not too influenced by the space between granules, meanwhile it is more inifluenced by structures, such as: a) fracture, b) fissure / crack, and c) conduit.

According to Kusumayudha (2000, 2004), Bribin-Baron underground river system is included in the Wonosari-Baron hydrogeology sub-system. Which is characterized by the presence of surface flow which goes underground. Their types of aquifer are semi-unconfined aquifer, unconfined aquifer, and perched aquifer in the rainy season. Also there is an underground river overflow. This sub-system is highly controlled by fracture structures that have larger dimensions than other sub-systems (Kusumayudha, 2004).

BRIBIN UNDERGROUN RIVER

The cave forming process will be difficult on massive limestones. Because of the cave formation and its orientation is controlled by the geological structure in the limestone (Kusumayudha, 2004). Geological structures can be found in the form of fractures, faults, and rock layers. In Gunung Sewu area, there is a correlation between structural patterns, fractures, drainage pattern on the surface, and drying patterns in some caves (Kusumayudha, 2000, in Khusumayudha 2004).

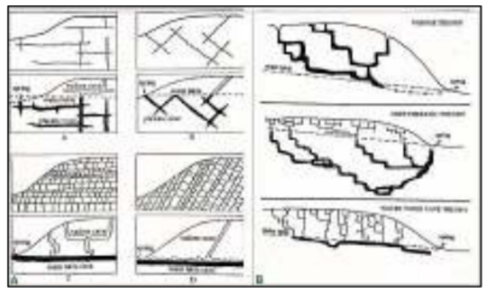

Figure 4 (A) Forming process of the cave that controlled by faults and fractures structure; (B) Cave forming process on limestone that located on karst area based on Water Table Theory (White, 1988, in Khusumayudha, 2004)

Bribin underground river is an underground river that interpreted flowing from Tambakromo, Ponjong, Kunung Kidul, and end at Baron Beach (Mac Donald and Partners, 1984, in Adji, 2011). Along the Bribin River there are karst caves which have function as karst windows or cave windows. The source of water in Bribin River comes from surface which seeps through the weak zones which produce secondary porosity in carbonate rocks such as faults and fractures

Figure 5 Bribin River System (Mcdonald and Partners,1984 at Adji, 2011)

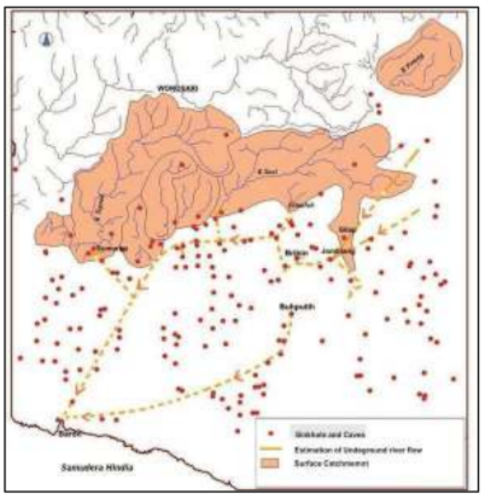

Figure 6 Caves and Sinkhole Distribution Map (MacDonald and Partners, 1984 at Adji 2011)

RESULT AND DISCUSSION

There are several control factors that can be a trigger for Bribin underground river overflow. They are rainfall, volume and water discharge, also the presence of karst windows. Karst Window is likened to the entrance and discharge of water from surface to underground river or the opposite. This Bribin River overflow can be explained by a related vessel system

Bribin Undeground River Overflow

Bribin river overflow that occurred in December, 2017 can be explained by the analogy of the vessel connected or the pipe connected. Where the holes in the pipe are likened to karst windows like caves, fractures, holes that become the entrance and exit of water to the underground river flow. While the pipe body is likened to an underground river flowing place. If the fluid entering of the holes and exceeds the capacity of the pipe, it will come out or overflow through another hole.

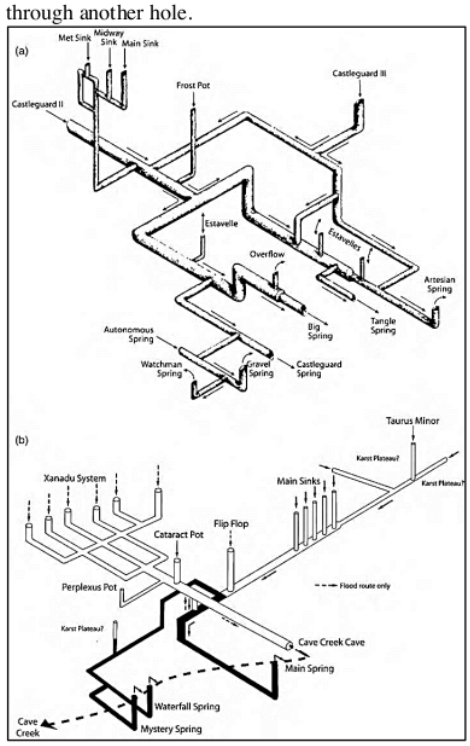

Figure 7 a) Proportional geometric model of Castleguard II conduit system, Canada. Reproduced from Smart, C.C. (1983b), in Ford and William 2007 (b) Cave Creek floodwater maze system, New Zealand. Reproduced from Crawford, S.J. (1994) in Ford and William 2007

Figure 7 is an example of underground river water modeling in several places, namely (a) Castleguard II conduit system, Canada and (b) Cave Creek floodwater maze system, New Zealand. Where there are several water entry points to the underground river then it is channeled to another hole which is in low topography. Both of these modeling can provide a basis that explains how the underground Bribin River overflow occurred. Then it can be interpreted factors that support the occurrence of overflow, they are:

1.Rain Intensity

Underground river water sources, especially in karst area, mostly come from the surface. Water conditions in karst area are very affected by the season and weather. Indonesia which has a tropical climate has two types of seasons that change every six months. On rainy season usually take place from October to March. During the rainy season, rainfall in Indonesia will rise as well as in the Gunung Kidul area. The higher rainfall will provide a high water supply too. The high supply of water entering the underground river system causes volume and flow velocity to increase.

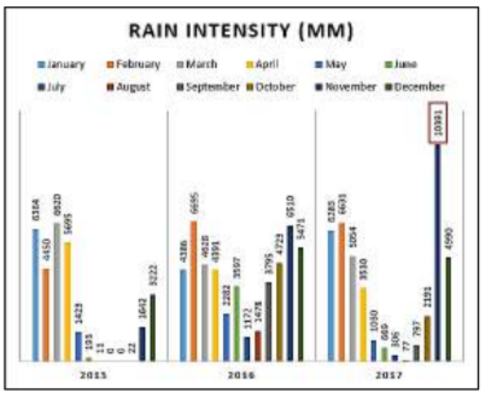

Figure 8 Rain Intensity Diagram (Agriculture and Food Services of Gunungkidul Regency, in BPS Statistic of Gunung Kidul Regency, 2018)

From the graphic of rain intensity diagram above shown that there is rain intensity anomaly happened on November, 2017. Therefore, we can conclude that the rain intensity happened on November, 2017 become one of the factor that causes Bribin underground river flow.

2.Flowing Discharge

Some researchers have measured the river flowing of Bribin underground river. Based on Subratayati (2008), Bribin River has a discharge between 800 liters/second – 1,500 liters/second. Meanwhile, according to the Center for Research and Development of Water Resources (2010), the underground river discharge in the dry season reaches 1,000 liters/second. According to the Center for Water Resources Research and Development (2010), Bribin River has a very large water storage capacity, it is 400,000 m3.

3.Over-flow Location

Based on the results of field observations and interviews of local communities at three observation locations namely Ngreneng Cave, Bribin Cave, and Sindon Cave, those were confirmed as the location of Bribin River overflow.

Ngreneng Cave is located at an altitude of about 200 m and at this location the river Bribin appears on the surface. Bribin Cave is located at an altitude of about 250 m. The river is inside. Sindon Cave is at an altitude of 280 m, the river is inside. So from the three caves that have the highest risk of overflowing, the Bribin River is Gua Ngreneg because of the lower tpography and the location of the river that appears on the surface.

From the identification of three observation locations, there were some similarities. These following three locations are identified with several parameters.

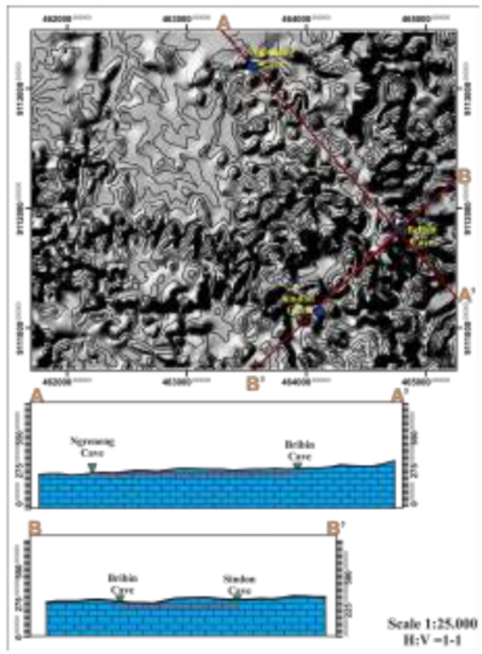

Figure 9 A-*A' and B-B' section of cave and under*ground river based on topography

Table 1 The possible risks list on the study area

Location Cave	Risks
Ngreneng Cave	1. Overflow inundates plantations and fields. 2. This location is a spring that is usually used for bathing and washing. So that when there is an outflow, citizens access to the spring will be stop. 3. Inundating the road. 4. Risk of damaging electric poles and can disrupt the electricity.
• Bribin Cave • Sindon Cave	1. Risk of damaging the water supply installation facility. 2. Risk of damaging water pump equipment.

	3. The citizen's clean water supply will stop. So that, it is detrimental to them.

Table 2 Identification of Observation Location

No.	Locations	Parameter					
		Landform	Function on karst system	Topography	Hydrology	Geological aspect	Socio-function
1	Ngreneng Cave	Spring, river, and karst cave.	As a kasrt window, in a karst system, this cave become an entrance and exit of water to Bribin River and as a spring.	Located on a lower topography than its surroundings, morphology resembles the shape of basin.	It is included in the Wonosari-Baron sub-system. The flowing discharge is around 30 liters/second (surface discharge) and as a spring where the flow of water comes directly from the surface Bribin river.	Lithology are reef limestones at the upper part and layered limestones (calcarenite) at the lower part. Also there are lapies and fracture structure.	Become a tourism area, source of clean water for local communities, and spiritual place.
2	Gua Bribin / Bribin 1	Karst cave	As a karst windows, Bribin river location is far enough from the cave entrance. Also there is karst underground river flow.	Topography on the outside of cave is relatively lower than around the cave, with steeps slopes and looks like a basin.	It is included in the Wonosari-Baron sub-system. We do not doing a discharge measurements due to the conditions on subsurface dam were still not fixed after an overflow, so it was still dangerous. Water flow is a direct supply from the Bribin River.	Lithology on the cave is carbonate rocks with massive structure and layered on the lower part. Also there is reef limestones, fracture and fault indication, and lapies structure.	-This location is functioned as a pumping installations for clean water to supply water needs in Semanu Sub-district and its surrounding. -Pumping installations have been installed by the Public Works Department in Gunung Kidul. -As a spiritual site.
3	Gua Sindon / Bribin II	Karst cave		Topography on the outside of cave is relatively lower than around the cave, with flat until steeps slopes and looks like a basin.			-This location is functioned as a pumping installations for clean water to supply water needs in Semanu Sub-district and its surrounding. -There are underground drilling wells and dams. This dam used to accommodate the river water flow and pumped out.

EVALUATION

This evaluation was done by using SWOT analysis. SWOT analysis uses parameters such as strength, weakness, opportunities, threats, to get the assessment area. of Bribin underground river and karst cave on study

Table 3 SWOT Analysis

No	SWOT	Remark
1	Strength	1. It has scientific value, especially for geoscientist 2. As a clean water source for the community 3. As a recreation site on Ngreneng Cave. 4. Some sites have economic value (Gua Bribin dan Gua Sinden) 5. Already has a road access 6. As a water resource for agriculture 7. Has spiritual value for communities around 8. Classified as periodic river type (based on discharge), which is a river that has a large water discharge during the rainy season and a small water discharge during the dry season but the water still flows 9. Has a large flowrate and water storage capacity
2	Weaknesses	1. Dangerous area to river over-flow 2. Some areas are have landslide potential 3. The three areas have potential for collapse lands 4. Difficult access 5. Have no mitigation system yet 6. The communities do not understand yet about the dangerous potential i Bribin river.
3	Opportunities	1. Geotourism development 2. Rejuvenation of existing facilities 3. Has a good potential to developed become a micro-hydro power plant 4. Conservation of caves on Bribin river 5. Community empowerment of Bribin River area
4	Threats	1. Training and introduction to a disaster risk for community 2. Make an Early Warning System 3. Installing a discharge measuring tools on each cave 4. Installing a nature-disaster

CONCLUSION

1. The hydrological system in study area is a kasrt hydrological system that highly controlled by dissolution process and affects secondary porosity. Bribin-Baron underground river is included in the Wonosari-Baron hydrogeology sub-system which is characterized by the presence of surface flow which then goes underground.
2. Underground river overflows can be explained by the principle of the corresponding vessel or pipe. If the fluid is the water entering one of the holes

exceeds the capacity of the pipe, it will come out or overflow through another hole.

3. Interpretation results indicate the occurrence of underground river overflow is controlled by factors such as rainfall, flow rate, and location of the karst window as a weak zone to become a water in and out way.
4. The three locations from the identified above are kasrt cave which is one of the karst windows, the topography is low and resembles a basin, have fracture and faults structures, thick carbonate lthology, and it is flowed by the main stream of Bribin River.

RECOMMENDATION

1. Conduct training and introduction to disaster risks to the community. This training and introduction is useful so that people understand about the Bribin River both its benefits and disadvantages.
2. Create an Early Warning System for the Bribin River. Early Warning System aims to provide information about the potential overflow of the Bribin River. Like weather warnings, heavy rain, which can trigger overflow. This system can be managed by the relevant government such as disaster management agencies.
3. Installing a debit measuring device. This tool can be installed on the Bribin River flow which is exposed at the surface. Like in Ngreneng Cave. Where people can directly monitor the increase in flow discharge from the Bribin River. So that people can be prepared if there are indications of river overflows.

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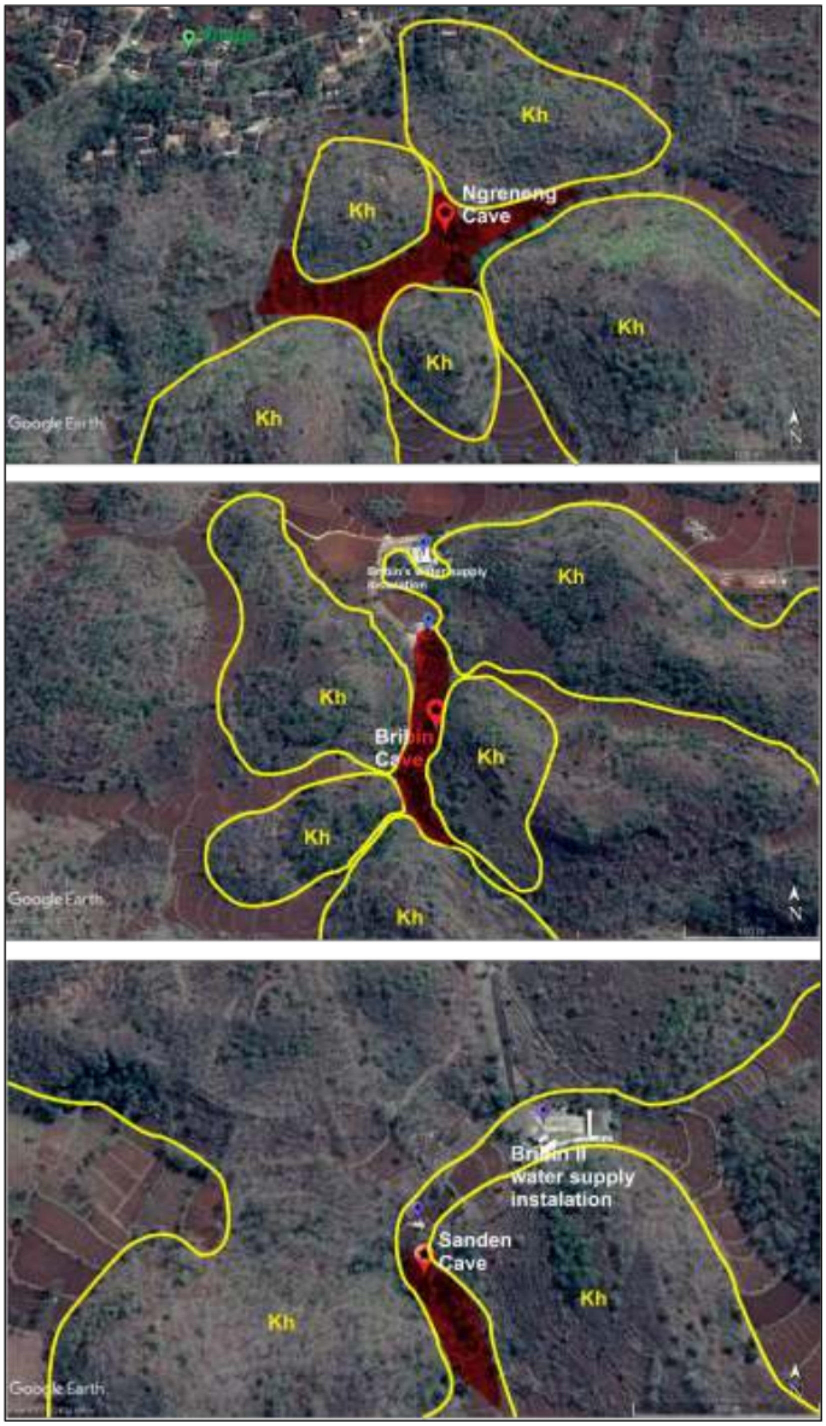

Figure 10 Map of affected zone potential by the overflow of Bribin River (Source: Google Earth, 2018, interview, observation)

Figure 11. Cave Conditions


Shiiki Hall
Bus stop
Center Zone 1
Ito
Guest House
Kyudai Big Orange mae
Kyudai Center Zone-Iriguchi
INAMORI Center
Kyudai Kogakubu mae
Big Orange
Center Zone 3
Kyudai Rigakubu mae
Center Zone 2
Big Sand
Symposium Banquet
on 8th of Dec.
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