THE PASSAGE CHARACTERISTICS AND POTENTIAL OF MBAH WAJIB CAVE IN TAMBAKREJO VILLAGE - SUMBERMANJING WETAN DISTRICT – MALANG REGENCY

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ABSTRACT

The cave passage is a natural form that develops in karst area. The cave passage is the sign of karst development. Mbah Wajib cave is located in southern mountains of Malang regency. There are certainly few studies of it, so the aim of this study is to find out the characteristics of the passage and the potential existed in this cave. Geomorphological approach became important in identifying the characteristic and the potential of this cave. Speleomorphology analysis and surface topographic features identification were used to get information related to the surface and subsurface. Morphometric analysis was used to show the dimension and levels of the cave passage. Cave passage interpretation was used to get the patterns developed on the cave passage. The measurement result in the field showed that the condition of Mbah Wajib cave passage is dominantly wide in shape rather than high. Meanwhile, the cave morphometric analysis showed that the cave is in unconfined condition. The morphometric index showed that the cave has a large complexity with a combination of vertical and horizontal passages. The development of the cave passage is dominated by structural and hydrological control which is adjacent to the rock layers. Water flow input comes from closed basins or ponds that assemble inside the cave. The development of cave level showed that there are three levels; first, a phreatic passage; the second level is an epiphreatic condition which is a fluctuation in the groundwater level; the third level is developing a vadose passage.

Keywords: *Karst, cave passage, groundwater*

INTRODUCTION

Malang Regency has the appearance of a karst landscape which located in the southern part of Java Island. The southern mountains are raised obliquely (Pannekoek, 1949). This landscape is located in the Miocene Wonosari Formation. The process of lifting and folding may occur again in the Plio-Pliotocene, followed by a process of denudation. This tectonic activity only resulted in tilting the Wonosari Formation to the south with 10^{o} (Suyanto, et al., 1992).

The development of karst area is identically signed by the presence of caves,

subterranean rivers, closed basins and other features. The appearance have been identified in Malang regency previously (Impala, 2012; Fauzi, et al., 2015; Labib, et al., 2019; Suprianto, et al., 2017; Salaka, 2018; Sahrina, et al. 2022). The existence of these features distinguishes it to other landscapes.

One of the endokarst appearances is the existence of Mbah Wajib cave. It is vertical and horizontal, and has subterranean river (Salaka, 2018). The aim of this study is to find out the characteristics and the potential of the cave that can be used by surrounding people. The appearance can be seen in Figure 1.

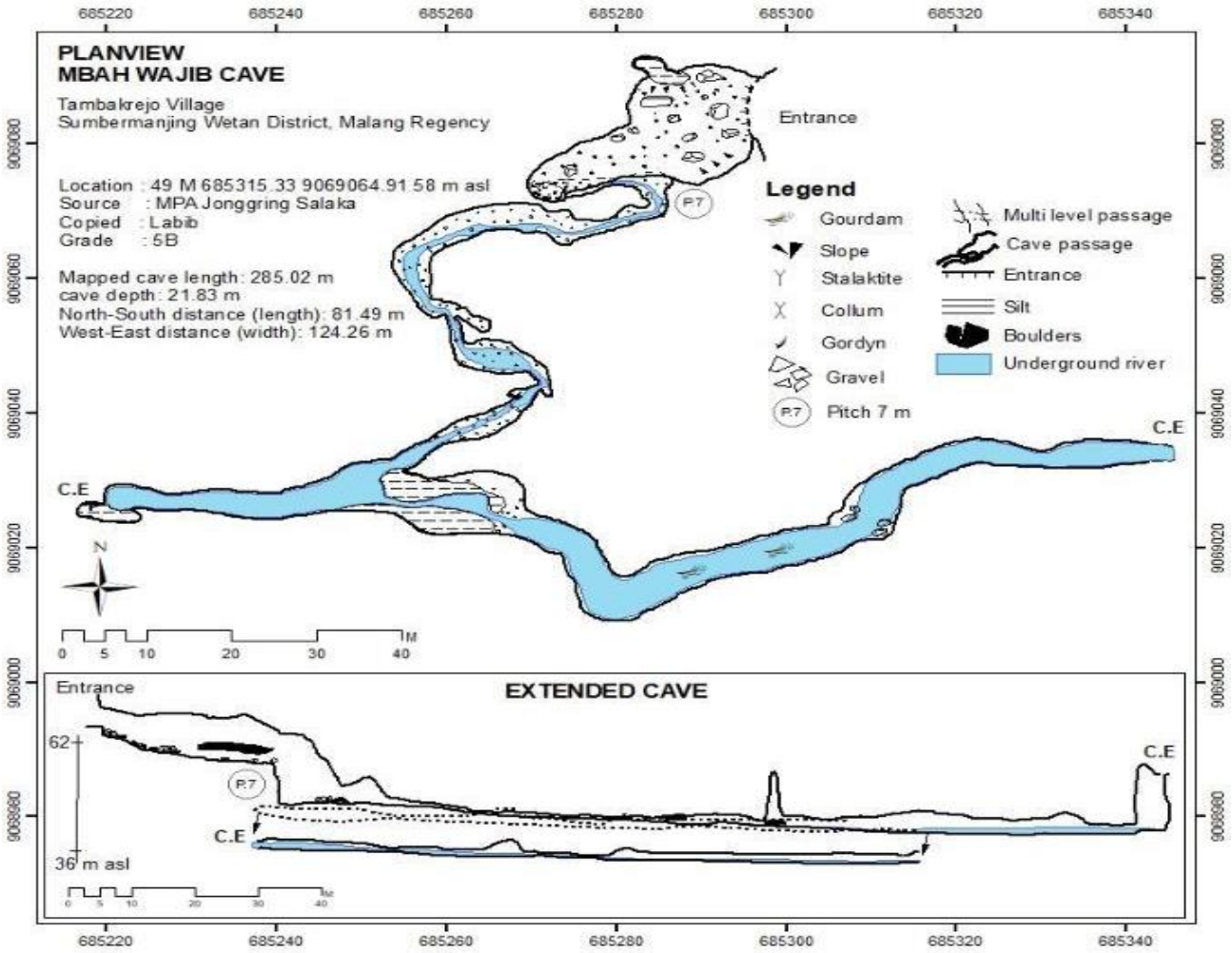

Figure 1. Mbah Wajib Cave Map

RESEARCH METHOD

This research was carried by conducting field survey. The location was taken placed in Mbah Wajib cave and the surroundings area. The result if the field survey used for making maps (Laksamana, 2005; Haryono, et al. 2016; Fauzan MRM et al, 2021). Morphometric analysis was done by using several parameters. Cave map analysis was used to see the pattern of the cave that develop (Klimchouk, 2006; Iguzquiza, et al., 2011; Piccini, 2022). The analysis of the landscape around the cave entrance was carried out using a drone. The existence of water stream inside the cave showed the potential that meets the water needs around research area. Survex software was used to make the centreline of the cave. Compass software was used to make block diagram. Meanwhile, rose diagram was used to see the dominant cave passage directions. Besides, to see the cave level using frequency analysis, width and height ratio calculation to see the

dominant formation at various cave passage height. (Piccini, 2011).

The potential sources existed in the cave passage would certainly focus on the surface condition and the characteristics of the cave passage. Figure 2 explained the research framework of analysing the potential existed in the cave. The geomorphology approach was used in analysing the appearance.

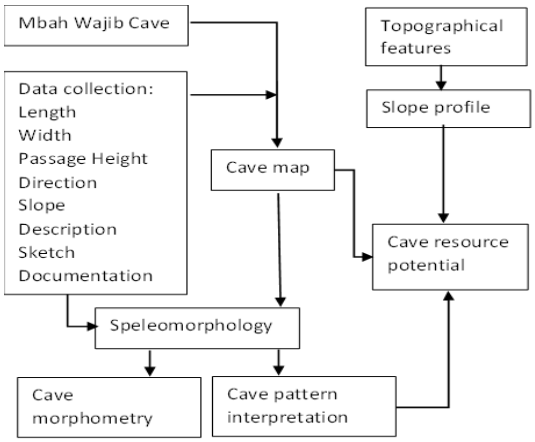

Figure 2. Research Framework

RESULTS AND DISCUSSION

Cave is natural passage that can be visited and entered by human. Cave in a form of passage has dimension in each segment. Table 1 shows the value from different cave morphometric parameter. The length of the cave is approximately 285.02 meter during the data collecting process in real dimension; with the depth from the top to the bottom part of the cave passage is about 21.83 m. The large of the cave area is taken from the widest part cave passage, while the cave passage itself is smaller than the cave area. Likewise with the volume of cave passage and volume of rocks, which have small volume is the density of cave passage, it's indicating that the passage does not consisted of complex branch. Likewise, the porosity of the cave has a small value, where the passage still forms a single formation with few branches. Coverage area represents the area of the cave passage in the cave area, which includes a value of 13%.

In the morphometric index, it can be seen that the Mbah Wajib cave passage has a high Complexity Index value indicating the passage has complex conditions with vertical and horizontal passages. The horizontal and linear indexes have almost the same value indicating the existence of dominant horizontal passages, while the vertical index has a slightly lower value indicating that the vertical passages are were not well developed in Mbah Wajib cave. The dominant formation in this cave passage has a wide shape. This can be seen from the ratio of the length and width or the average width of the high cave passage. The calculation results of the cave morphometric parameters can be seen in Table 1.

Table 1. Morphometric of Mbah Wajib Cave

Parameter	Mbah Wajib Cave
Cave length (m)	285,02
Cave depth (m)	21,83
Rectangular length (m)	81.49
Rectangular Width (m)	124,26
Cave area (m^2)	10.125,95
Cave volume (m^3)	3.413,9
Passage area of the cave (m^2)	1.289,82
Rock volume (m^3)	221.049,43
Specific volume	11,98
Density of cave passages (km/km^2)	0,03
Cave porosity (%)	1,54
Cave area coverage (%)	13
Verticality index	0,08
Horizontality index	0,46
Linearity index	0,36
Horizontal complexity index	0,95
Mean width (m)	35,53
Length/width (m/m)	8,02

Source: Salaka, 2018; Data processing, 2022

The calculation of the cave passage segment dimensions is shown in Figure 3, which shows the dominant cave passage width value. A value less than 1 indicates that the cave passage forms an oval passage, while those more than 1 and above will form a flat tunnel. The passage formations above are spread over various heights of the passage. In the passage adjacent to the cave entrance is the formation of a rectangular passage.

Furthermore, when entering the vertical passage, you will find an oval passage, until you meet a flat passage. This continues also in the further oval-shaped passage and when entering the underground river it will form a flat passage.

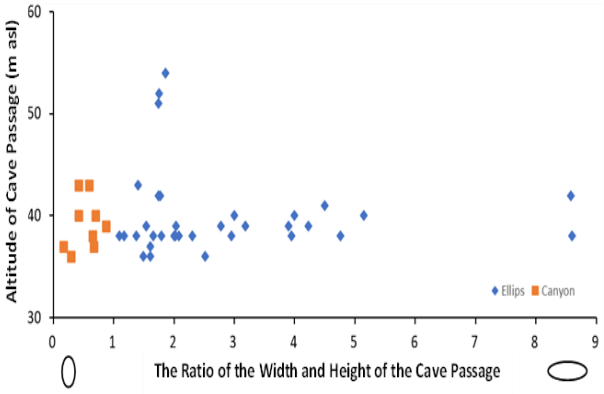

Figure 3. Cave Segment Ratio Varieties at Several Heights

The development of the Mbah Wajib cave passage is dominated in the West-East direction. The dominant direction of this passage is in the area of the underground river that leads to the West-East. While the North and South sides are more on the fossil passage. The block diagram of the cave passage shows the development of the cave passage which is controlled by the bedding plane on the West-East side (Figure 4).

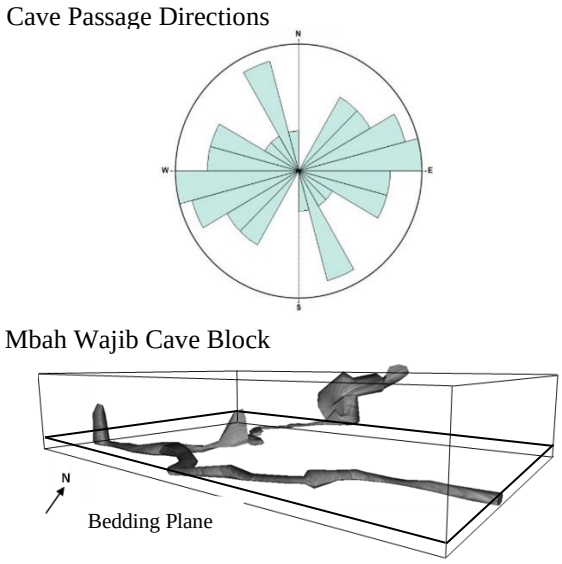

Figure 4. Passage Direction(a) and Cave Block Diagram (b)

The condition of the Mbah Wajib Cave passage has three levels of cave passages. The first level is located at an altitude of 54-51 m above sea level, when entering the cave passage; you will find a chamber, which contains many chunks of rock. At this level, light can still be seen through, because it located at the entrance of the cave. In this condition, the passage is dry, but during the rainy season, the flow of water will enter the cave, which will then be swallowed below the surface. Gravitational processes developed in this passage, it can be seen by the amount of lumps in this area. Ornament in this passage is not well developed.

The changes of cave levels are marked by the presence of shafts. The shaft formed in this lane has a depth of approximately 7 meters. At this level it is found at a height of 50-42 m above sea level. At this level you will find seepage of water that will lead to a subterranean river. The formation is different on the first level. The roof of the passage tends to narrow. This is indicated by bowing down or crawling when we enter the cave. There found rocks too. There are some ornaments that develop on this level such as stalactite and flowstone.

The development of the passage on the third level is at the altitude of 41-36 m above sea level. At this height, it is marked by the dimensions of the roof of the cave which have begun to rise. Though the roof of the cave contains a lot of silt, it possibly from cave mud deposits during the flood. The flow of water from the second level and the first level (during the rainy season) will gather at this level. At this level you will find branches, the one to the right is the downstream of the river and the left is the upstream from the subterranean river Mbah Wajib. The direction of the passage to the right has a deep subterranean river condition, approximately 2 meters deep. The condition of this passage is like a basin or water reservoir, which indicated that the subterranean river has disappeared. When entering the next tunnel, you will find a muddy track. This track is difficult to trace, because of the vertical and muddy passages. Entering the passage led to the upstream, you will see the

chamber, but the longer the cave, the roof will be shorter. In addition, the cave passage will be narrower and filled with subterranean river, so that at the end of the tunnel it cannot be traced because the passage is covered with water. Figure 5 shows an overview of the cave passage levels. The passage that showed horizontally is the level of the cave passage, while a drastic change in elevation indicated that there is a change in the level of the cave passage.

Mbah Wajib cave that has been explored and mapped certainly has a unique appearance.

It can be seen in the development of the cave level. In addition, there is potential for subterranean river that is in the first level. This subterranean river is a river that continuously flows throughout the year. The water infiltration is far from the location of the cave. This subterranean river becomes an important asset in the future needs of water resources. Figure 6 shows the appearance of the cave passage with several narrow passages and at the bottom there is a subterranean river flow.

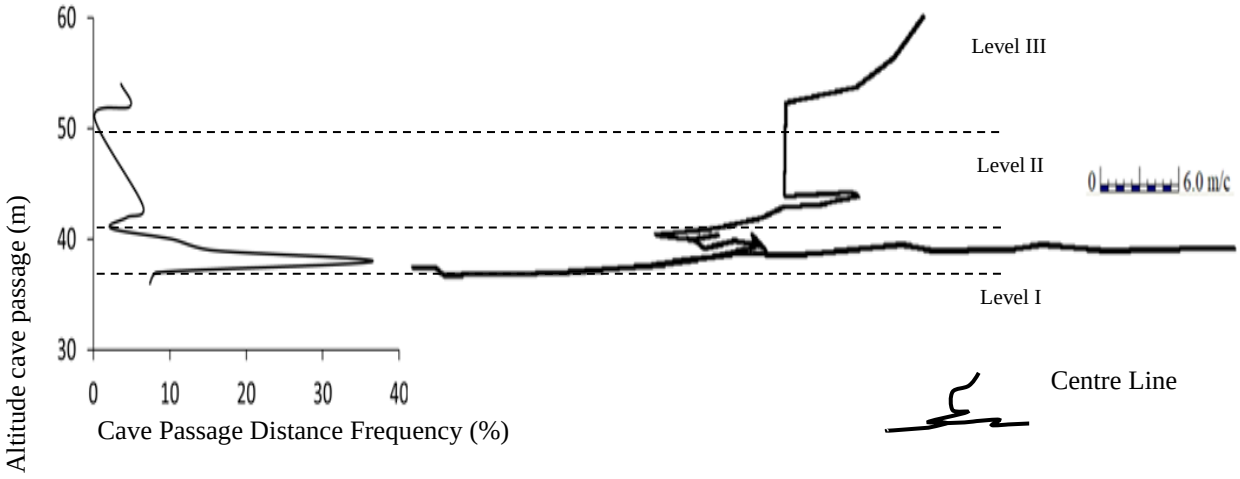

Figure 5. Mbah Wajib Cave Levels

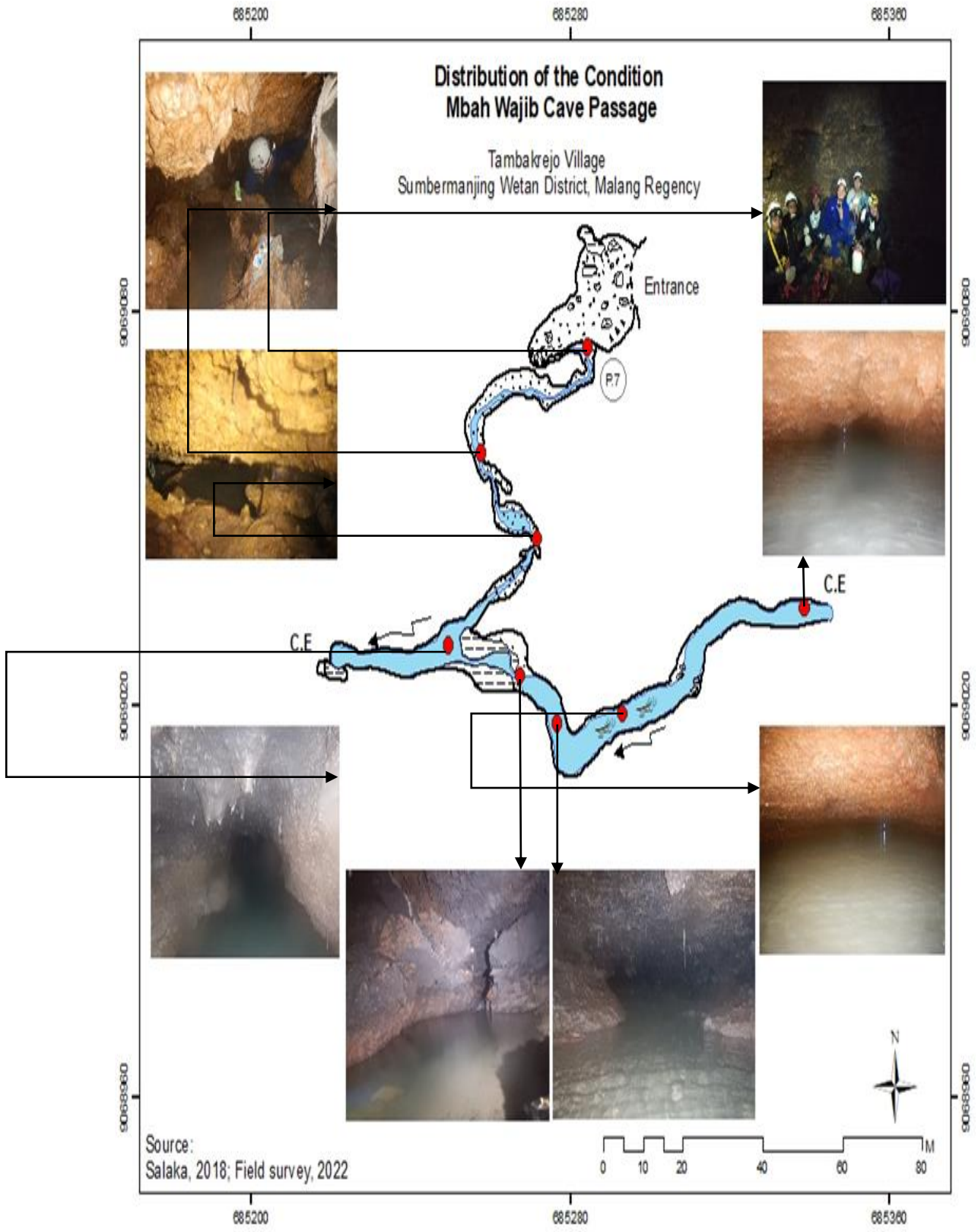

Figure 6. Distribution of Mbah Wajib Cave Passage Conditions

The use of subterranean rivers can be done by lifting water from below the surface to the surface. The water point taken is under the branching in the form of the water basin. This lifting of water certainly requires a strong water pump, given the large difference in elevation from the water source to the water reservoir for the community. Figure 7 is a scenario of a water pipe from a subterranean river to a water reservoir. There is an elevation difference of approximately 80 m with a track length of approximately 500 meters.

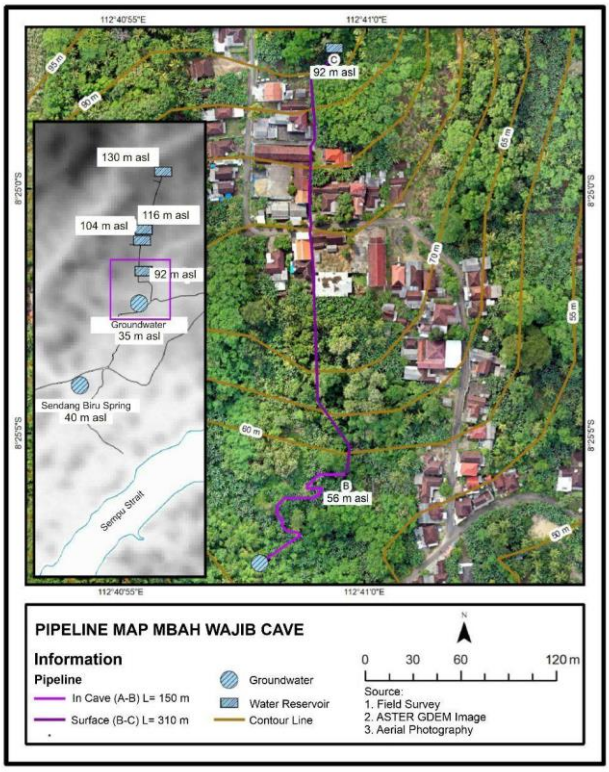

Figure 7. Water Flow Lifting Scenario in Mbah Wajib Cave

DISCUSSION

Mbah Wajib cave passage has different characteristics. The results of the cave planview interpretation showed that this cave passage has a curvilinear passage pattern. Palmer (2007) defines this pattern as having an affix from the surface such as the presence of a doline, sinkhole, or ponor. Meanwhile, the developing control is the control bedding plane. By segmentation of the passage, the Mbah Wajib cave passages are divided into 3 zones; the vadose zone, the epiphratic zone, and the phreatic zone. In the current vadose condition, the process that is developing is the gravitational process, because there is no subterranean river, and it can cause rock collapse (Klimchouk & Andrejchuk, 2003). The epiphreatic zone is characterized by changes in groundwater level (Audra & Palmer, 2013). The cave passage can still be dissolved because of the subterranean river that develops in this condition. The phreatic zone is at the end of a subterranean river passage that cannot be traced back. There are generally 2 passages development controls, namely hydrological and structural controls (White, 1988).

The hydrological process is more developed in this passage because the cave has a subterranean river. This can be seen by the appearance of the planview map of the cave which is winding due to the formation by hydrological processes. In addition, the calculation for each cave segment also shows that there is a larger passage width indicating that the cave passage segment has experienced a lot of dissolving horizontally, not vertically. The existence of a vertical passage that developed, was due to the process of rock removal in the past so that there was a drastic change in the elevation of the cave passage.

The parameter values for passage density, area coverage, and cave porosity show that the cave is in an unconfined development (based on the results of the Klimchouk study, 2006), with water sources coming from meteoric water, where many caves appear in this condition (Ford & Williams, 2007). This condition is also found in several caves in Java (Ashari, 2013; Suprianto, et al., 2017; Labib, et al., 2019; Gussyak, et al., 2022). Gravitational dissolution process through rock fractures. The flow of water comes from the surface area that goes into the cave. The cave morphometric index shows the cave developed in a complex way with the development of vertical and horizontal passages. However, the horizontal tunnel dominates with the formation of the hydrological process that influences the dominance of the cave passage direction.

Piccini (2011) provides an overview of cave passages levels, where the frequency of the length of the passage at the same height will form the level of the cave passage. The level of the cave shows a change in

groundwater level and the formation of the cave passage. Each level change, the groundwater level will decrease, which will form the decoration of the cave passage. This can be seen in the chamber near the entrance of Mbah Wajib cave, where no subterranean river flow has been found, only during the rainy season when water enters the cave. Mbah Wajib cave's groundwater level must be at the lowest level. The levels of the cave passages are also seen in the Banyu Cave system and its surroundings which form 4 levels of the cave (Labib & Suprianto, 2019), while Mbah Wajib cave has 3 levels.

The use of cave passages is generally used as a tourist spot (Harmony & Pitoyo, 2012; Sahrina, et al., 2022) , but there are also people who use caves as a water source for community needs (Subratayati, 2009; Sigit, et al., 2015; Mardiko & Sulistiyowati, 2017). Seeing the conditions in Mbah Wajib cave, of course, the subterranean river in the cave can be used for the clean water needs of the people of Tambakrejo Village. However, water resources in karst are prone to drought and environmental pollution (Sahrina, et al., 2020; Widyastuti, et al., 2021) and mining may occur at the study site, as has occurred in several areas. (Raharjo & Haryono, 2020)

CONCLUSIONS

The cave passages have interconnected shapes and dimensions. The cave passages form patterns that make the cave more varied. Mbah Wajib cave is a complex cave with vertical and horizontal passages. The hydrological process in this cave is also dominant in shaping the decoration of the cave passage. There are 3 levels of the cave which are divided into 3 zones, namely vadose, epipreatic, and preatic. The three zones also have different conditions. Subterranean rivers certainly have potential that can be utilized by the surrounding community.

RECOMMENDATIONS

The underground river in the Mbah Wajib Cave can be used by the community, but it must pay attention to the community's needs and water availability so that there is a balance in the use of underground rivers.

ACKNOWLEDGMENTS

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