Sediment Deposit of Merapi Mount Eruption

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ABSTRACT
The eruption of Mount Merapi at the end of 2010 has completely changed the landscape in the affected areas, namely at the foot of the mountain to the south and west. The potential deposit of material that has been spewed out at the time of the eruption is estimated at around 140 million m3, this is a fairly large volume compared to several previous eruptions. From this analysis, three lines are obtained that describe the elevation of the riverbed for both the longitudinal and transverse sections. The addition of sediment deposits mostly occurs in the upstream area and is estimated to come from rain lava floods. This study provides an overview of the condition and position of the riverbed elevation, both longitudinal and transverse in the Gendol, Kuning and Boyong rivers and the volume in each cross section. Normalization of the river is needed to provide space for the river channel, so that if there is a flood, the lava rain can be filled again and not endanger the surrounding area.

***Keyword**: Eruption, sediment, volume, Merapi*

I. Introduction

The eruption of Mount Merapi at the end of 2010 has completely changed the landscape in the affected areas, namely at the foot of the mountain to the south and west. The potential deposit of material that has been spewed out at the time of the eruption is estimated at around 140 million m3, this is a fairly large volume compared to several previous eruptions. Besides burying several villages in Magelang and Sleman Regencies, the material is also carried far downstream through the river channel that originates at Mount Merapi, this material is known as the debris flow. The deposit resulting from the eruption can be seen as a problem as well as a potential that must be managed properly to minimize the negative impact and maximize the positive impact. To manage it effectively, it is necessary to create a distribution map that can inform the location of the deposit as well as the volume of each at that location.

This mountain is very dangerous because according to modern records it erupts (peak activity) every two to five years and is surrounded by very dense settlements. Since 1548, this mountain has erupted 68 times. Magelang City and Yogyakarta City are the closest major cities, under 30 km from the peak. On the slopes there are still settlements up to a height of 1,700 m and only four kilometers from the summit. Because of its importance, Merapi is one of the sixteen world volcanoes included in the Decade Volcanoes project. [1]

The characteristics of eruptions since 1953 are the rush of lava to the top of the crater accompanied by periodic collapse of the lava dome and the formation of hot clouds (nuée ardente) that can slide down the slopes of the mountain or vertically upwards. This type of Merapi eruption generally does not emit an explosive sound but a hiss. The peak dome that existed until 2010 was the result of processes that took place since the 1969 gas eruption.

Figure 1. Morphology of Mount Merapi

The morphology of this crater was formed after the eruption in 1961. In general, the plateau of Merapi's peak is composed of lava domes that have not collapsed. [2] Several areas on the Merapi peak plain outside the main crater emit a lot of volcanic steam, namely in the Gendol and Woro areas, the southeastern part of the peak plain. Very steep slope : reaching > 25° Elevation : 2960 – 1800 m dpi. The dangers of Mount Merapi can be divided into primary hazards and secondary hazards. Primary hazards are hazards that arise as a direct result of an eruption. Meanwhile, secondary hazards are hazards that are indirectly caused by eruptions or eruption products. Primary hazards are hot clouds of eruptions, eruptive material throwing and eruption ash. Secondary hazards are lahars, damage to houses and shelter and even food shortages. Lahar is a flow of mud and rock from erupted material which due to the addition of water from the rain is carried down and flows as a concentrated stream. The two elements that make up the lahar are lahar material in the form of sediment resulting from eruptions on the slopes of Merapi and water that comes from rain. The lava material that has the potential is material from the eruption that is still new and has not been compacted. That is why the risk of lahars is quite high if there is heavy rain in the days/weeks after the eruption. So far, the flow generally flows in river channels that disgorge at Merapi.

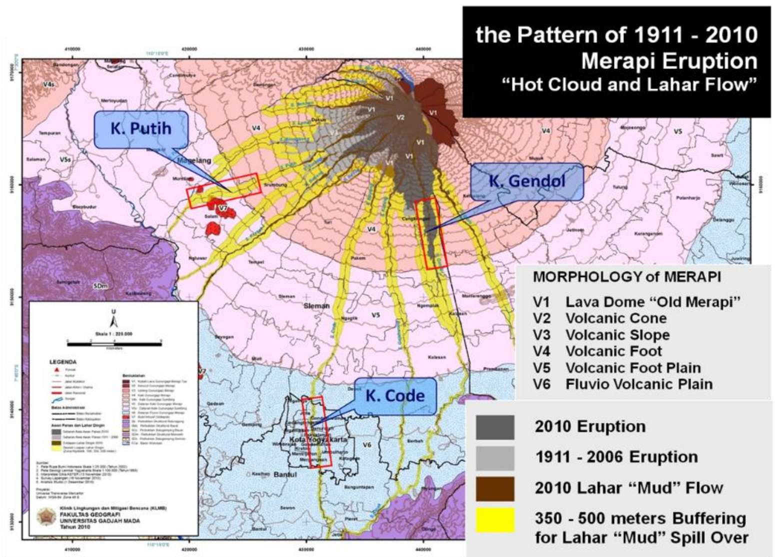

Figure 2. Map of the eruption of Mount Merapi (1911-2010)

Figure 3. Gendol Opak Watershed Sediment Deposits After the 2010 Mount Merapi Eruption

II. Literature Review

The Gendol River, with its catchment area of 66 km2 and the river length of about 22 km, originates from the south east of Mount Merapi. Nineteen sabo dams have been built in order to anticipate and control sediment disaster. The most upstream dam is Kaliadem (+1.100 msl) and the most downstream dam is consolidation dam of GE-C0 (+163 msl). Sand mining occurs at several points along the river and cause environmental damage. In order to conserve environment and to maintain sediment balance a proper sediment management is required. The result of the study shows that the sabo system in Gendol River effectively works to control lahar flow. As a conclusion, the existing sabo dams are able to maintain sediment balance in Gendol River. The possible amount of sand mining is estimated about 1.253.422 m3 and the allowable daily sand mining volume is estimated about 836 m3 per day (Rahmat, et al, 2008).

Rahmat, A., Legono, D., Kusumosubroto, H., 2008, Pengelolaan Sedimen Kali Gendol Pasca Erupsi Merapi Juni 2006, Forum Teknik Sipil No. XVIII, May 2008. [3]

The volcanic belts in Northeast Russia contain abundant deposits of the subvolcanic group. These are related to early or late magmatic facies (rhyolite basaltic series) of volcanodome uplifts in calderalike fea tures. At these depths mostly HS deposits are formed. The typical representatives of this group include the Karamken, Kupol (Northeast Russia), and Aginskoe deposits. Detailed surveys of many ore areas can detect ear lier "preporphyry" epithermal deposits and later ones that are related to porphyry intrusions. The earlier deposits are shallower, but are more sharply rejuve nated, their later mineral associations are not infre quently characterized by higher temperatures (up to the skarnoid ones, as is the case for Dukat) and by higher silver concentrations, as far as being domi nantly silverbearing. East Russia has a real potential for the discovery of major volcanogenic deposits of noble, base, and rare metals, considering the poor knowledge we have of its volcanogenic belts and zones. In this connection it is an especially important task to study the entire diver sity of hydrothermal formations in areas of recent, as well as ancient, volcanism (Sidorov, A. A., Volkov, A.V., Savva, N.E., 2015). [4]

Sidorov, A. A., Volkov, A.V., Savva, N.E., 2015, Volcanism and Epithermal Deposits, ISSN 0742-0463, Journal of Volcanology and Seismology, Vol. 9, No. 6, pp. 349–357. © Pleiades Publishing, Ltd., 2015.

III. Problem Identification

Based on the observations and identification, the locations were determined to include the Gendol River (Opak River), Yellow River, Boyong River (Code River) because they have the greatest potential for sediment deposits compared to other areas. The Gendol River is an area with the greatest potential for mineral deposits compared to the Boyong River and the Yellow River.

IV. Objective

In total, there are 13 rivers that originate at Mount Merapi and have the potential to drain rain lava. However, this study only prioritizes 3 (three) rivers, namely the Gendol River, the Yellow River, and the Boyong River. The choice of these three rivers is because they have a large deposit potential in addition to the large number of mineral mining activities in these rivers.

V. Methodology

In this study, the analysis of map processing was carried out using two software, namely AutoCad Civil Land Development 9 and ArcGis 10. The analysis aims to determine the volume of deposits after the eruption and the volume of deposits remaining after excavation. This is intended to be able to provide recommendations to the competent authorities to grant mining permits for mineral minerals based on certain locations and quotas. This analysis uses 3 maps with different years, namely: Contour map in 2009 (before the eruption of Merapi), Contour map in 2010 (post-eruption of Merapi), and Contour map in 2014 (November 2014). Map of 2009 sourced from the Information and Geospatial Agency (BIG) with contour intervals of 12.5 m. This map has the lowest accuracy compared to the other two maps (2010 and 2014). Map of 2010 (post-eruption of Merapi) sourced from satellite imagery conducted by PPK Merapi BBWS WS Serayu Opak. While the existing map in 2014 is planned to be taken from Quickbird satellite imagery with a resolution of up to 0.8 m. However, because the desired time is not shooting at the required time and place, it is replaced with another source, namely aerial photography. The map generated from this aerial photo has a better resolution than satellite imagery, which is 0.3-0.6 m. Another advantage of aerial photography when compared to satellite imagery is that shooting can be done at any time according to needs, shooting locations can be determined as needed and 3D image processing is much better. An illustration of the source map used in this study is presented in the figure below.

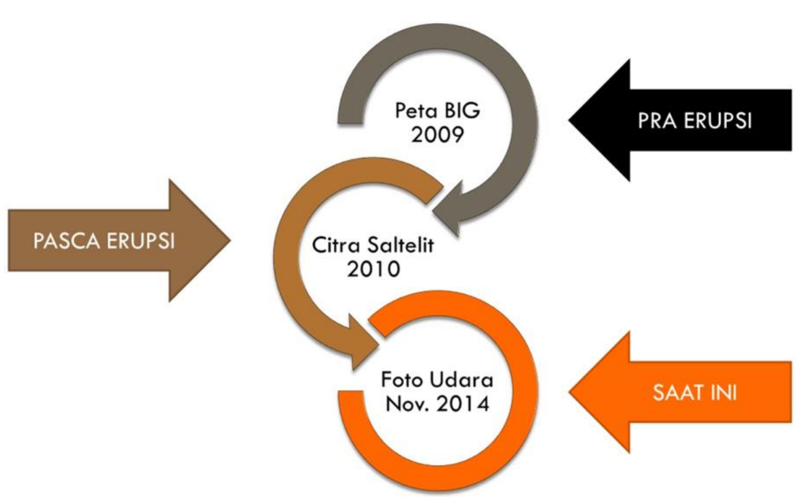

Figure 4. Maps used in this study

In total, there are 13 rivers that originate at Mount Merapi and have the potential to drain rain lava. However, this study only prioritizes 3 (three) rivers, namely the Gendol River, the Yellow River, and the Boyong River. The choice of these three rivers is because they have a large deposit potential in addition to the large number of mineral mining activities in these rivers.

Analysis with GIS

As stated earlier, this map analysis aims to determine the dynamics of the volume of mineral deposits resulting from the 2010 eruption of Mount Merapi. Therefore, in this study by comparing three maps (2009, 2010, and 2014) three conditions will be obtained, namely:

1. Comparison of maps for 2009 and 2010 will result in potential mineral deposits.
2. Comparison of maps in 2009 and 2014 will result in the remaining potential mineral deposits. This condition is the basis for recommendations in granting mining permits
3. A comparison of the 2010 and 2014 maps will reveal the potential that has been explored.

In this study, only sedimentary deposits in the river channel will be analyzed. This is related to the recommendation for the mining of minerals from the Merapi eruption proposed by the Sleman and Magelang Regency Governments. Mining permits are only allowed in the river channel up to the riverbed limit before the eruption. This arrangement aims to preserve the environment and river morphology. Comparison of 2010 and 2014 maps will result in the potential that has been explored.

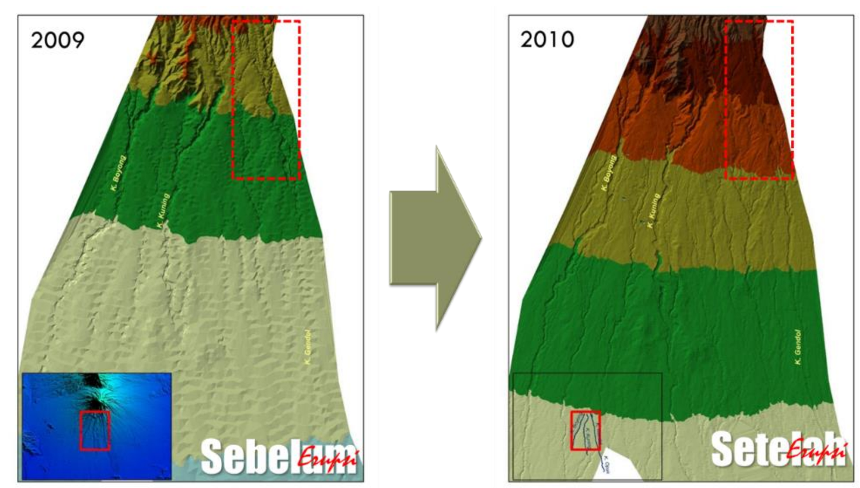

Figure 5. Comparison of river morphology (map 2009-2010)

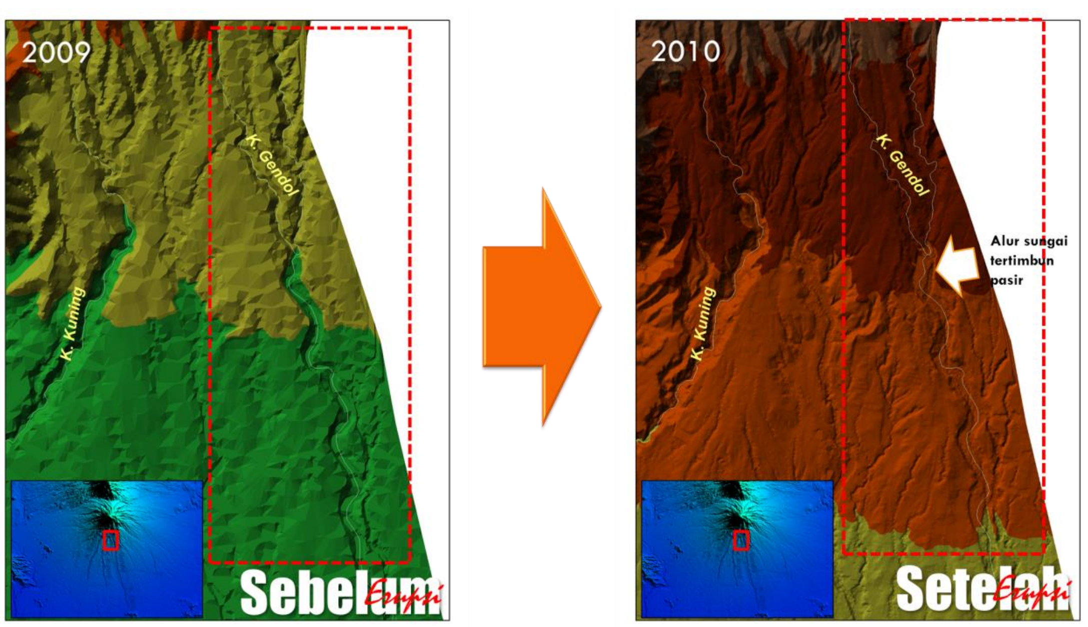

Figure 6. Comparison of the morphology of the Gendol river (map 2009-2010)

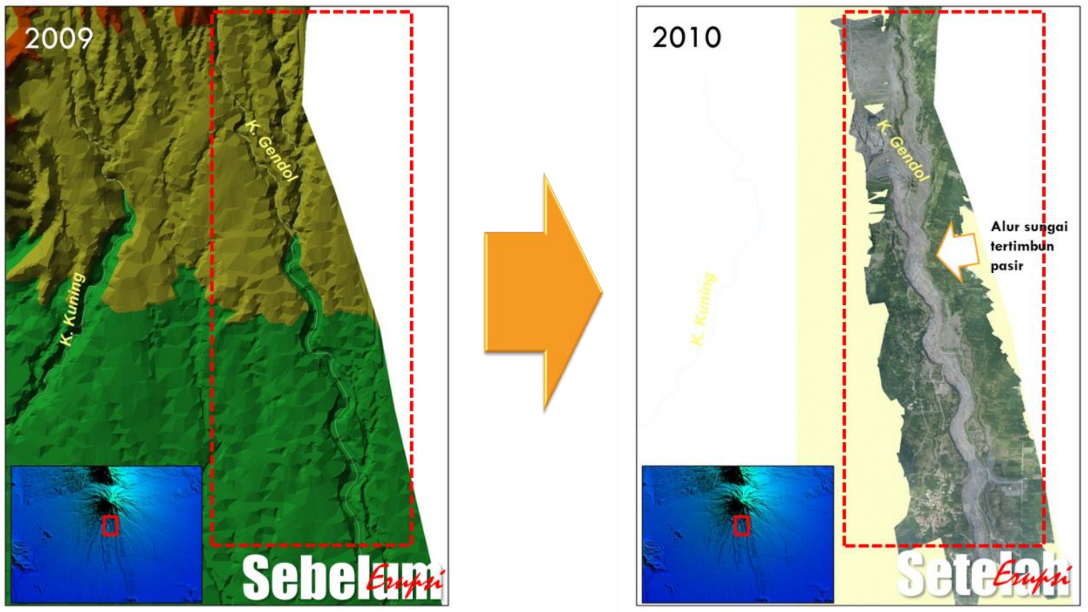

Figure 7. Gendol river flow covered with sand

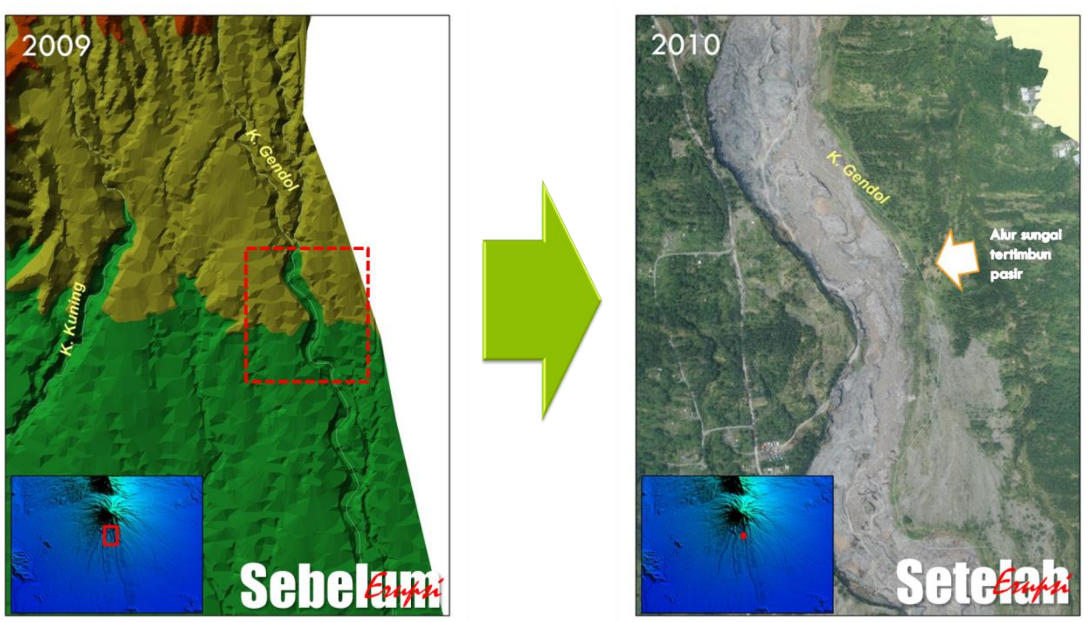

Figure8. Sand heap on the Gendol River

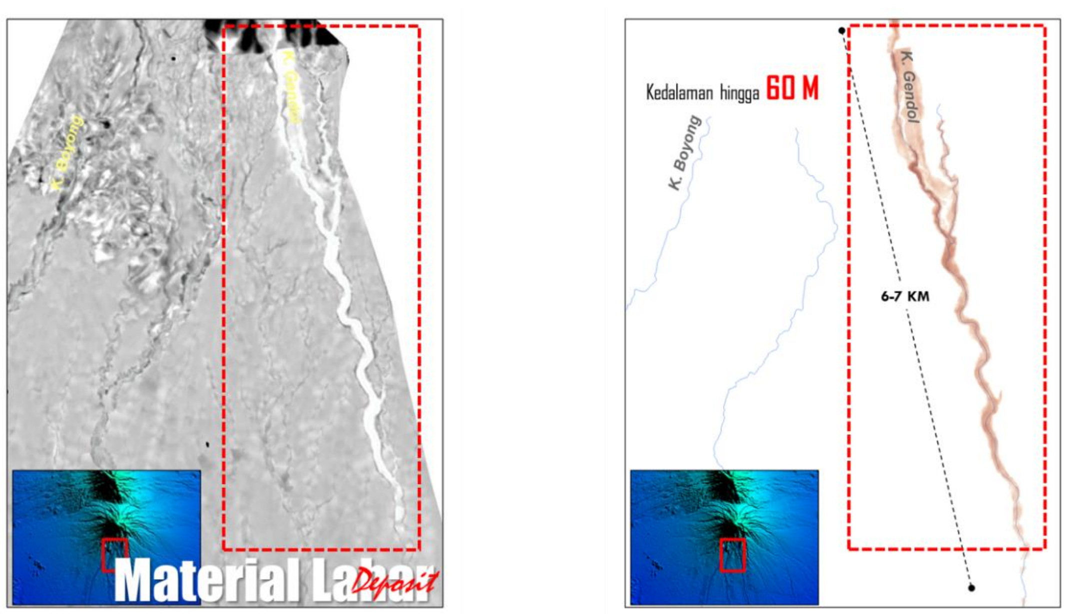

Figure 9. Distribution of rain lava and mineral deposits in the Gendol River

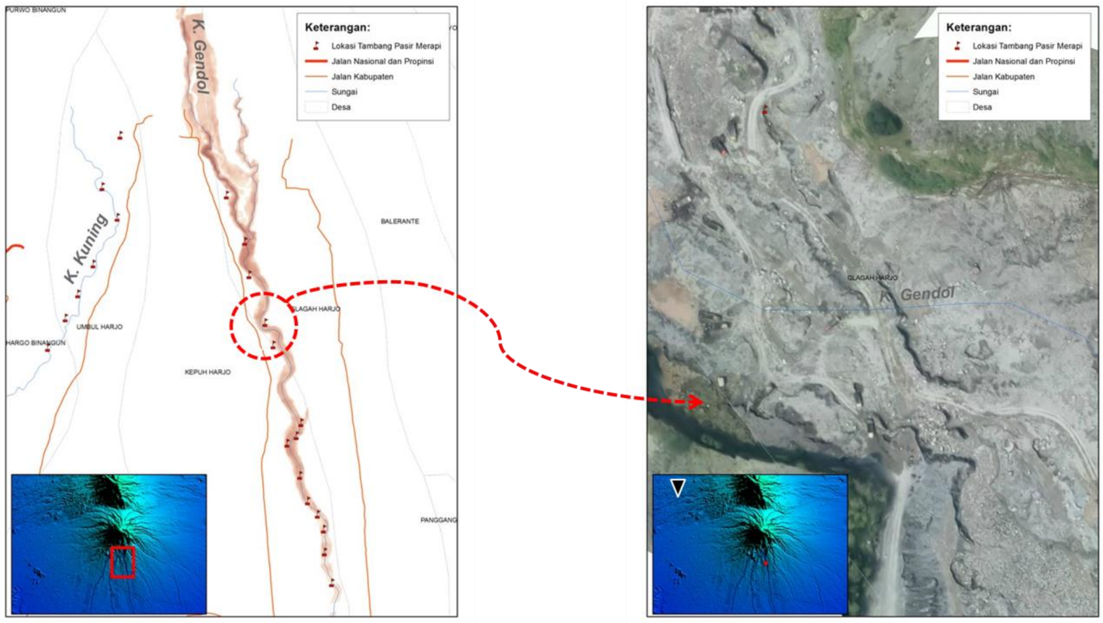

Figure 10. Detailed description of mineral deposits in the Gendol River

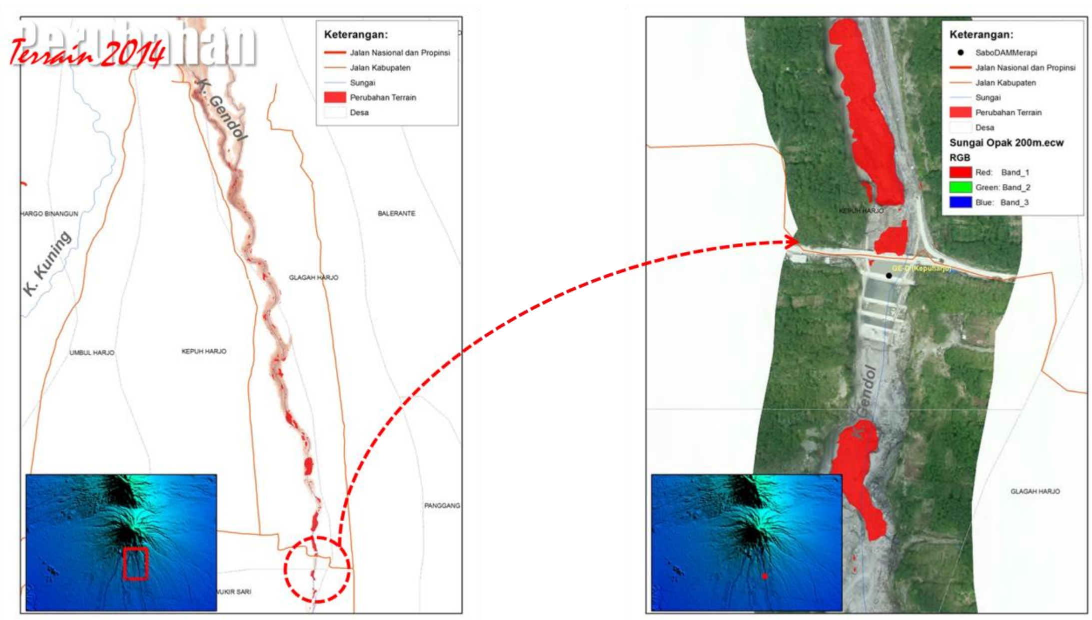

Figure 11. Changes in river morphology due to mineral mining activities

Analysis with AutoCAD

From this analysis, three lines are obtained that describe the elevation of the riverbed for both the longitudinal and transverse sections. The longitudinal cross-sectional image as presented in Figure 4.13, shows that in some places the deposit was added (green color) and in some other places it was excavated to exceed the initial river bed (Year 2009).

The addition of sediment deposits mostly occurs in the upstream areas and is thought to originate from rain and lava floods. However, in some downstream areas where a lot of mineral mining activities are carried out, the elevation of the riverbed is actually deeper than the conditions in 2009. This is very dangerous and contrary to the existing laws and regulations. PP No. 38 of 2011 concerning Rivers has regulated the mining limit for mineral minerals in riverbeds, which must not exceed the initial riverbed. In addition to the longitudinal section, in this analysis a cross section is also made every 25 m. In each cross section, three riverbed elevation lines are made. In Figure 4.9 below, the 2009 elevation is depicted with a black line, 2010's elevation is depicted with a blue line and 2014 with a red line. Based on the analysis, there are three kinds of conditions, namely: (A) elevation in 2014 below 2010 but still above 2009 (normal condition), (B) elevation in 2014 above 2010 (addition of deposit) and (C) elevation in 2014 below elevation 2009 (overmining).

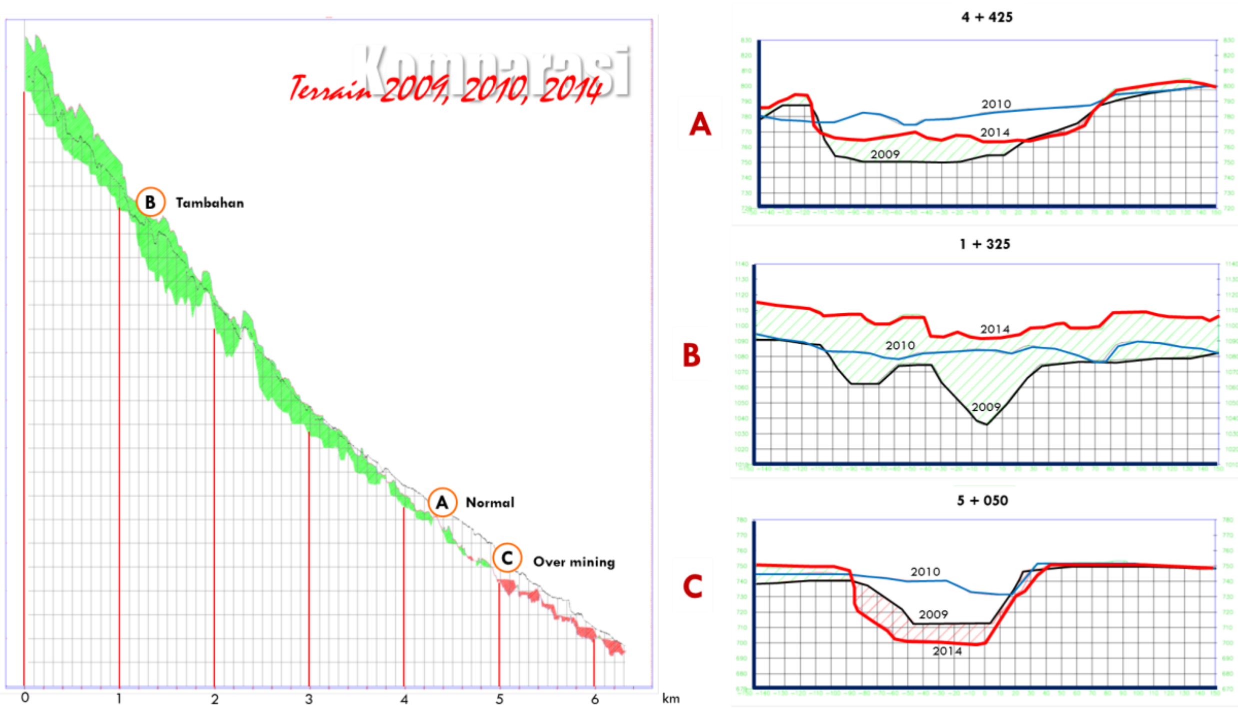

Figure 12. Longitudinal section and cross section

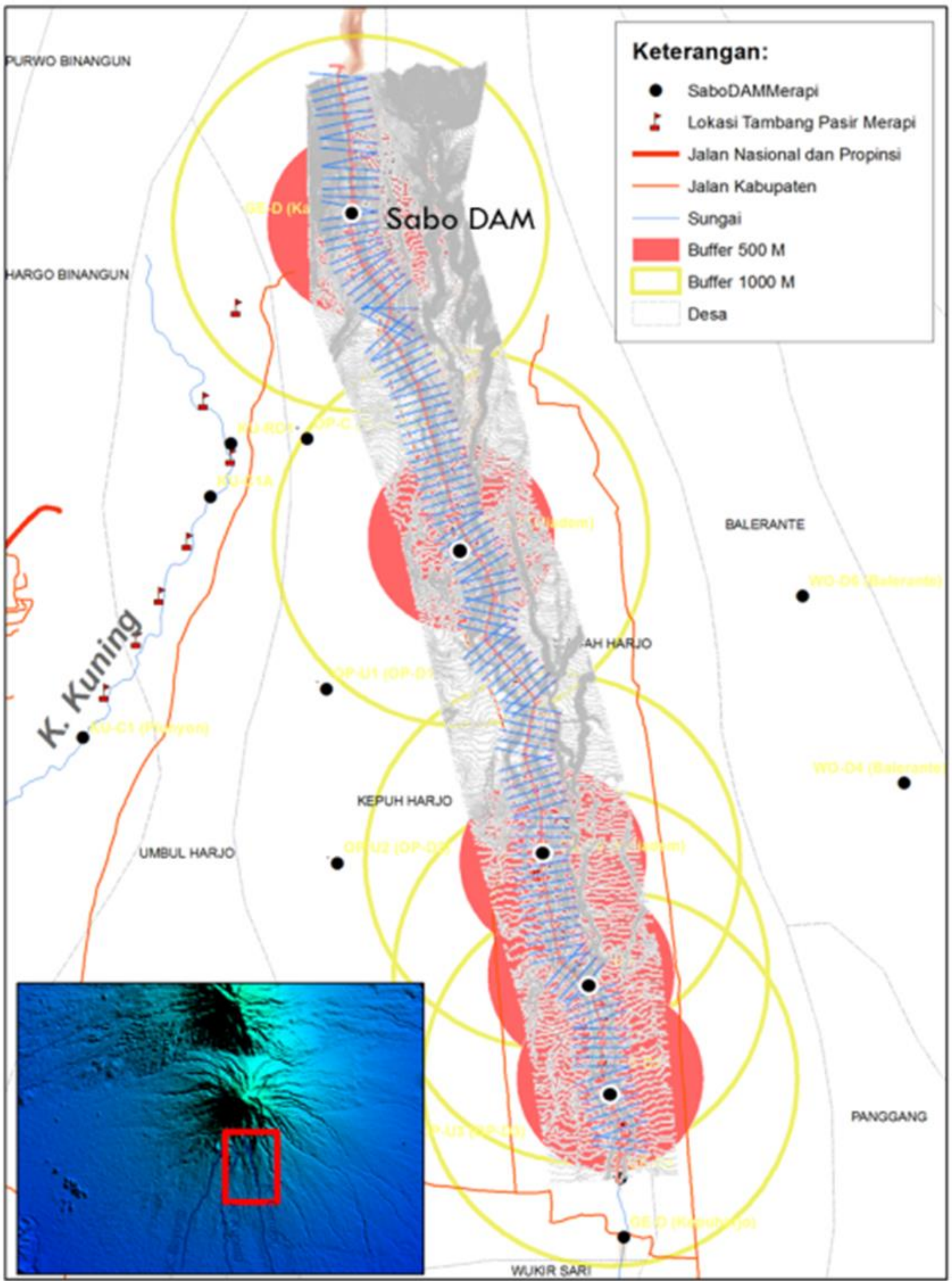

Figure 13. Layout cross section

Figure 4.14 above shows a cross section every 25 m in the Gendol River. Besides, it also describes the location of the Sabo Dam (black dot) complete with buffers with a distance of 500 m (red circle) and 1,000 m (yellow circle).

VI. Result and Discussion

Among the most important of the basic recommendations above is the deposit volume that can still be normalized (mined). In this study, a volume table per river cross section has been made with 25 m intervals. For certain purposes, river intervals can be made more tightly. This table can easily and quickly estimate the potential volume of existing sediments (November 2014). For example, if there is a mining permit application for a cross section of 1+000 to 1+500, it can be directly identified by adding up the Cut Volume column (yellow shading) and obtaining a volume of 5,030,060,3 m3. Thus, the quota that can be mined is 5,030 million m3.

Table 1. Illustration of calculating deposit volume

Station	Cut Area (Sq.m.)	Cut Volume (Cu.m.)	Fill Area (Sq.m.)	Fill Volume (Cu.m.)	Cum. Cut Vol. (Cu.m.)	Cum. Fill Vol. (Cu.m.)
1+000.000	8,715.5	179,164.2	0.0	0.0	9,196,584.5	1,665,508.6
1+025.000	8,605.7	216,514.8	0.0	0.0	9,413,099.3	1,665,508.6
1+050.000	8,432.1	212,972.1	0.0	0.0	9,626,071.4	1,665,508.6
1+075.000	8,638.8	171,443.6	0.0	0.0	9,797,514.9	1,665,508.6
1+100.000	9,091.8	221,632.4	0.0	0.0	10,019,147.4	1,665,508.6
1+125.000	9,805.6	226,634.7	0.0	0.0	10,245,782.1	1,665,508.6
1+150.000	9,625.9	242,893.0	0.0	0.0	10,488,675.1	1,665,508.6
1+175.000	10,533.6	251,993.1	0.0	0.0	10,740,668.2	1,665,508.6
1+200.000	10,577.3	263,885.4	0.0	0.0	11,004,553.6	1,665,508.6
1+225.000	10,438.8	230,297.1	0.0	0.0	11,234,850.7	1,665,508.6
1+250.000	10,958.6	294,396.7	0.0	0.0	11,529,247.4	1,665,508.6
1+275.000	10,336.0	266,182.0	0.0	0.0	11,795,429.4	1,665,508.6
1+300.000	9,884.9	252,761.0	0.0	0.0	12,048,190.4	1,665,508.6
1+325.000	9,212.4	276,545.5	0.0	0.0	12,324,735.9	1,665,508.6
1+350.000	9,122.9	229,191.9	0.0	0.0	12,553,927.8	1,665,508.6
1+375.000	9,952.1	238,437.3	0.0	0.0	12,792,365.1	1,665,508.6
1+400.000	9,989.7	227,312.7	0.0	0.0	13,019,677.8	1,665,508.6
1+425.000	10,436.6	255,328.0	0.0	0.0	13,275,005.8	1,665,508.6
1+450.000	12,225.0	283,269.4	0.0	0.0	13,558,275.3	1,665,508.6
1+475.000	14,710.1	336,688.1	0.0	0.0	13,894,963.3	1,665,508.6
1+500.000	8,995.3	152,517.2	0.0	0.0	14,047,480.6	1,665,508.6
1+525.000	9,290.9	228,577.1	0.0	0.0	14,276,057.6	1,665,508.6

5,030,060.30 m3

Currently there are 13 BMs of which 7 are in the Gendol River, 2 in the Yellow River and 4 in the Boyong River. The distribution of BM placement in each river is presented in the figure below.

Figure 14. Bench Mark Point of Gendol River.

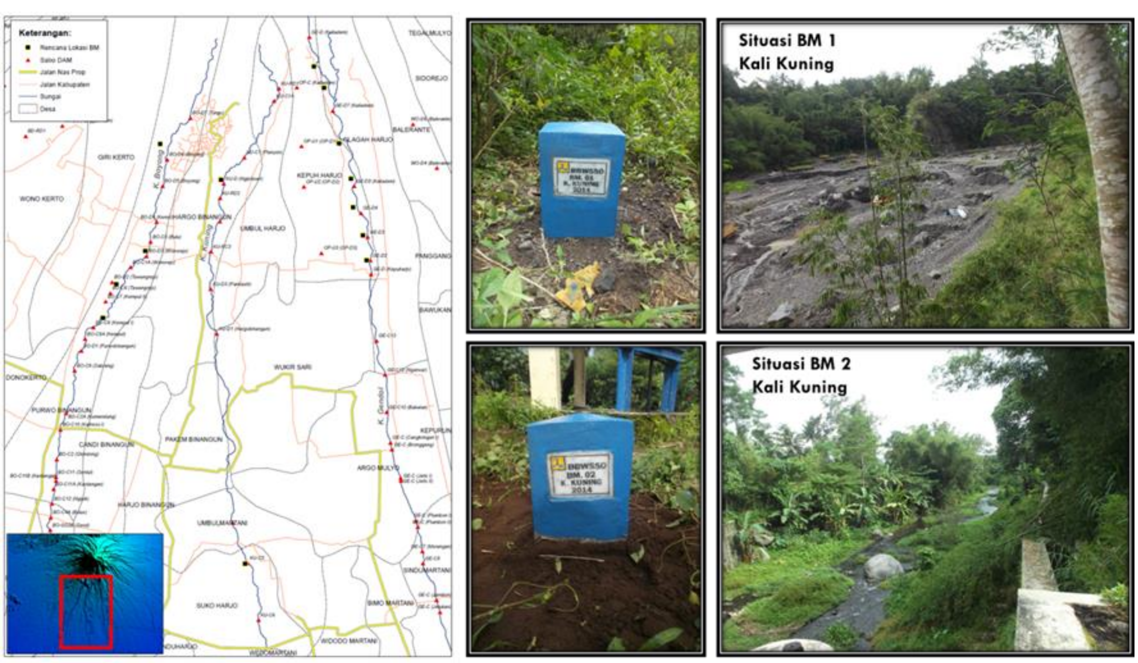

Figure 15. Bench Mark Point of Kuning River.

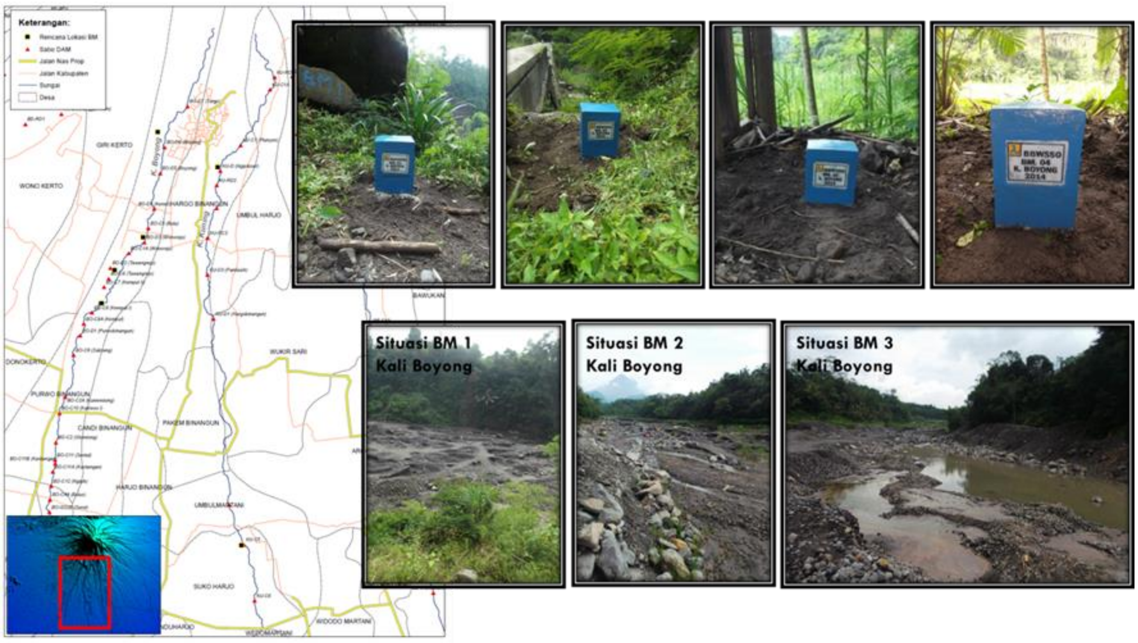

Figure 16. Bench Mark Point of Boyong River.

VII. Conclusion

Normalization of the river is needed to provide space for the river channel, so that if there is a rain lava flood it can be filled again and does not endanger the surrounding area. This study provides an overview of the condition and position of the riverbed elevation, both longitudinal and transverse in the Gendol, Kuning and Boyong rivers and the volume in each cross section.

VIII. References

[1] O. Soemarwoto, "Analisis Mengenai Dampak Lingkungan," 2007.

[2] T. W. S. H. P. Suparman. Soetopo, "Sabo Untuk Penanggulangan Bencana Akibat Aliran Sendimen," 2011.

[3] H. Rahmat, A. Legono, D. Kusumosubroto, "Pengelolaan Sedimen Kali Gendol Pasca Erupsi Merapi," *Forum Tek. Sipil No. XVIII*, 2008.

[4] N. . Sidorov, A. A., Volkov, A. Savva, "Volcanism and Epithermal Deposits," *J. Volcanol. Seismol.*, vol. 9, 2015.