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Managing the Mount Merapi sediments

by

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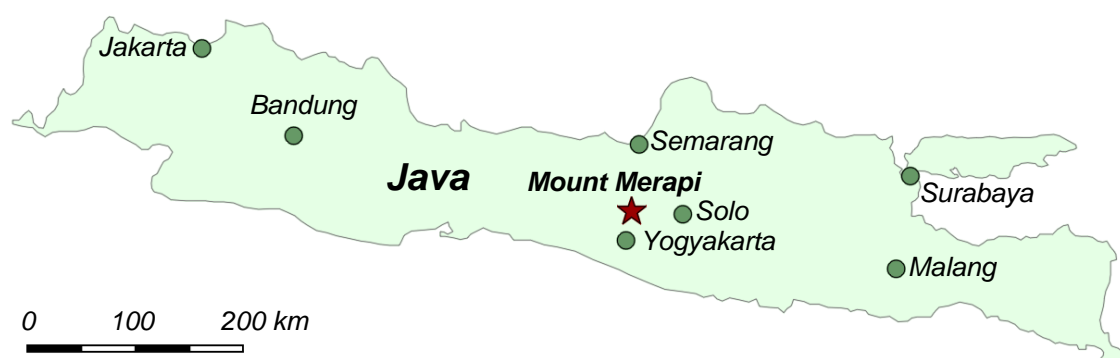
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Location map



Glossary

Lahar (word of Javanese origin): A flow of volcanic sediments suspended in water. A stagnant sediment deposit can turn into mud (and start moving, driven by gravity) during a strong rainfall, and can shift back to a stagnant deposit when the rain stops. The destructive capacity of lahar flows is related to their abrupt character and their high density

Flash floods: An abrupt flood wave caused by extreme rainfall and/or by collapse of some obstruction to the flow, for example a sediment deposit

Pyroclastic flows: A dense, hot mixture of gas and volcanic sediments, flowing downwards, driven by gravity; occurring abruptly during eruptions and causing casualties and other severe damage on its way

Sabo (word of Japanese origin): Sediment control

Scour: Erosion of the river bank or river bed caused by strong turbulence - for example on the downstream side of a structure generating turbulence by its disturbance of the flow

Summary

With 129 active volcanoes, Indonesia has achieved a particular expertise in managing the impacts of volcanic sediments.

Such sediments are carried first by hot pyroclastic flows and later as lahar, suspended in rainwater. In both cases, the flows are driven by gravity, so the sediment transport tends to follow the pattern of surface runoff. Therefore, the sediments find their way to the river beds. The lahar flows cause a strong scour, which in turn can destroy structures that come in their way, and the sediments themselves, once deposited, add to the flow resistance and the flood risk.

Mount Merapi, Central Java, had a major eruption in October-November 2010. It emitted some 150 million m³ of sediments.

The present paper describes the preventive and remedial measures to mitigate the impacts of this sediment load.

1 Introduction

Apart from other damage, volcanic activity can disrupt the surrounding river networks by abrupt deposition and subsequent flow of large amounts of sediments. This can increase the risk of floods, including flash floods; change the planform of the river network; and destroy roads, bridges, buildings and other structures.

The impacts are manageable to some extent. Appropriate preparedness and determined mitigation efforts can not prevent the damage, but can reduce it significantly.

2 Mount Merapi and its surroundings

Mount Merapi is a strato type volcano located 30 km north of Yogyakarta, Central Java. Its peak reaches 3,000 m above sea level. Being Indonesia's most active volcano, it erupts every four years on the average.

Figure 1: Mount Merapi



1.6 million people live in the city of Yogyakarta, and the whole area is densely populated. There are no less than two spectacular World heritage sites near the volcano: Borobudur Temple 28 km to the west, and Prambanan Temple 24 km to the south.

Due to the intermittent character of lahar flows, the morphological impacts can proceed for years. In 1971, the bed level of one river (Progor) increased by 5-6 m following a major eruption in 1969.

3 The 2010 eruption

Mount Merapi erupted on October 26, 2010, following weeks of increased seismic activity (and due warning from the national Center of Volcanology and Geological Hazard Mitigation). Major and minor eruptions occurred in the following weeks. Ash clouds reached heights of 5-6 km, and ash precipitation occurred over large parts of Java (including 2-3 cm of ash deposits at Borobudur Temple). During one explosion, on 30 October, sand was raining from the air at a distance of 10 km.

Eventually, the alert level was reduced on 3 December 2010.

This was the mountain's largest eruption since 1872. 341 people were killed (in many cases while disregarding evacuation recommendations). More than 2,000 homes were destroyed, and nearly 350,000 people were evacuated. Airports were closed and hundreds of domestic and international flights were cancelled. Financial losses are estimated at 781 million USD.¹

Figure 2: Lahar deposits in a river bed



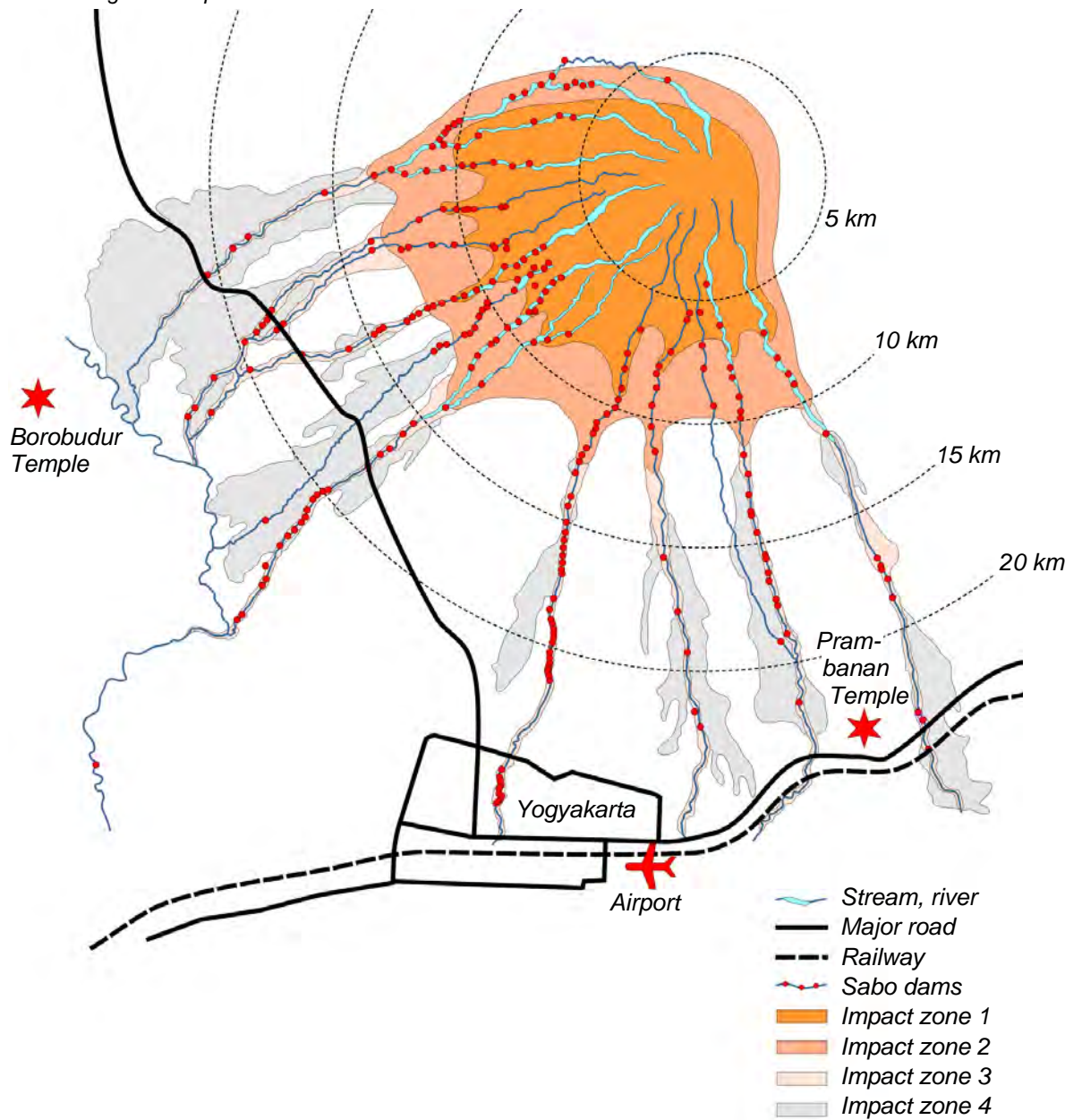
Putih River, near the Yogyakarta-Magelang highway, 12 April 2011

The map below shows impact zones from recent eruptions. Pyroclastic flows with temperatures of 600-800 °C extended 10-15 km and lahar flows 25-30 km. The 2010 eruption had its main impacts towards south, whereas previous recent eruptions mostly affected areas to the west and southwest. Potentially, however, pyroclastic flows and lahar flows can occur all around the mountain.

The map also shows the location of sabo dams (check dams for sediment retention). Please refer to the following chapter for additional information.

¹ USGS (Feb 11)

Figure 3: Impact zones and sabo dams



The total volume of sediments released during the 2010 eruption is estimated at 150 million m³.

Damage caused by lahar flows continues, for a period that is typically 1-2 years, but which can be up to 10 years.

4 Management options

The movement of sediments can be controlled in different ways:

- By sabo dams;
- by removing the sediments; and
- by vegetation cover.

4.1 Sabo dams

A sabo dam is a control structure (overflow weir) that reduces the flow velocity and retains the mud flows.

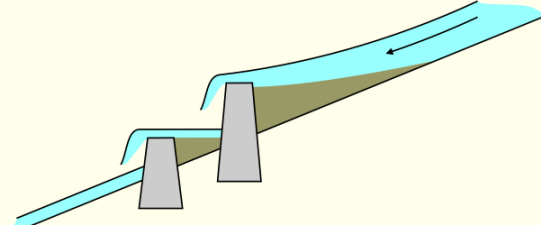
A sabo dam

A sabo dam is normally a pair of dams, a main dam for retaining sediments and a secondary one for protecting the main dam against scour. The secondary one can be skipped if the main one is founded on solid rock.

The structure reduces the flow velocity and retains sediments.

The retention capacity depends on the topography of the upstream river bed, but can be 100-200,000 m³.

Depending on the location, the structure can also divert water for irrigation, or even feed a micro-hydropower plant.



One single such structure has a limited effect. Rather, series of sabo dams are built along a river for incremental capacity. Around Mount Merapi, the upstream structures are designed to withhold boulders only, letting sand and gravel pass, to be captured by structures further downstream.

Figure 4: A sabo dam (with an outlet for irrigation)



It is important to maintain a certain basic level of sediment transport past the structures. Otherwise, there will be increased erosion in the downstream parts of the river system.

Around 200 sabo dams have been built around Mount Merapi since 1970. Many older ones are still operational, because the sediments are removed (as explained in the following section). Even when the sediment retention capacity is fully used, they still reduce the flow velocity.

4.2 Sediment removal

The volcanic sediments contain around 80 percent sand, which can be used for construction.^{2 3}

In consequence, the sand is extracted by scores of entrepreneurial operators. These pay around 200,000 IDR (120 USD) to load a truck (of 3-4 m³), and can then sell the sand for 500-700,000 IDR (300-430 USD).

One concern in this connection is that sand and boulders are sometimes extracted with little regard to river banks and structures, which can be further damaged by the activities. Regulation exists but is not well enforced.

Figure 5: Abstraction of volcanic sand



Pabelan River, near the Yogyakarta-Magelang highway, 12 April 2011

4.3 Vegetation cover

Covering the sediments with vegetation is an efficient and inexpensive way to retain them before they reach the river system. This can be done after 2-3 years, once the sulphuric gases have disappeared. Volcanic sediments are fertile, so the vegetation will grow readily.

Apart from the purpose of retaining sediment, it is also important to restore vegetation lost during pyroclastic flows. This can begin shortly after the eruption has ended.

² The gravel is not used, due to lack of strength, and is removed by sieving

³ The ash (fine sediment) component is well suited for cement production, but can only be extracted for a short period of time, until it is flushed away by the rain

5 Research

Balai Sabo, or Research Station for Sediment Control, is located in Yogyakarta. Its history goes back to 1982, when it was established with support from Japan. Today, it belongs to a family of 8 thematic research stations (Balai) under Research Institute for Water Resources, Agency for Research and Development, Ministry of Public Works.⁴ Related training is done by a separate unit.

Figure 6: Balai Sabo, Yogyakarta



Balai Sabo conducts research related to sediment-related calamities - not only caused by volcanic eruptions, but also land slides and slope failures - preparedness as well as mitigation.

Development of operational warning is a major activity.

6 Evaluation

Improved forecasting

In Indonesia, forecasting of major volcanic eruptions is working well, based on seismic monitoring and comprehensive experience. (Many seismic gauges near the volcano are destroyed during an eruption, but not until having served a useful purpose). Four alert levels are applied and are broadly publicized when there is a need.

There is a clear scope for better forecasting of flash floods and lahar flows. Challenges in this regard include

- a short lead time; and
- ground-based rain gauges being destroyed as a first thing during an eruption.

⁴

The other ones cover aquatic environment; coastal engineering; hydraulic structures; hydrology; irrigation; river engineering; and wetlands

During the 2010 eruption, rain gauges were destroyed within a 10 km radius, and solar cells on gauges further away were covered by ash.

Efforts are made to supplement the ground-based gauges with remote monitoring by radar and perhaps satellite.

Improved control of sand extraction

Removal of sand for construction is basically a win-win situation. Unfortunately, however, it happens that the extraction adds to the problems rather than reducing them. The sand is taken where it is easiest to access, which can be near roads and bridges. Hereby, the activities can enhance the destructive erosion caused by lahar flows.

Distance limits exist but are not always observed. There is a scope for improved awareness and better enforcement.

References

USGS (Feb 11): Thousands saved by accurate eruption forecasts of Mount Merapi, Indonesia. Volcano Watch. US Geological Service, Hawaiian Volcano Observatory

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