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Mitigation of hazards from future lahars from Mount Merapi in the Krasak River Channel near Yogyakarta, Central Java

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Mitigation of Hazards from Future Lahars from Mount Merapi in the Krasak River Channel near Yogyakarta, Central Java

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ABSTRACT

Procedures for reducing hazards from future lahars and debris flows in the Krasak River channel near Yogyakarta, Central Java, Indonesia, include (1) determining the history of the location, size, and effects of previous lahars and debris flows, and (2) decreasing flow velocities. The first may be accomplished by geologic field mapping along with acquiring information by interviewing local residents, and the second by increasing the cross sectional area of the river channel and constructing barriers in the flow path.

INTRODUCTION

In 1980 the U.S. Geological Survey (USGS), through the U.S. Agency for International Development (USAID) and the Ministry of Research and Technology of the Government of Indonesia (GOI), began a cooperative study of the characteristics, distribution, and mechanisms of landslides in Java. On January 31 and February 1, 1981, we made a reconnaissance of the east-west Krasak River channel about 15 km north of Yogyakarta, Indonesia (fig. 1), in order to evaluate the possible hazards that would result from future massive lahars coursing down the Krasak drainage. Mount Merapi, to the north of Yogyakarta, is the source of these lahars; the triggering events could be heavy rains, earthquakes, and eruptions of the Merapi volcano.

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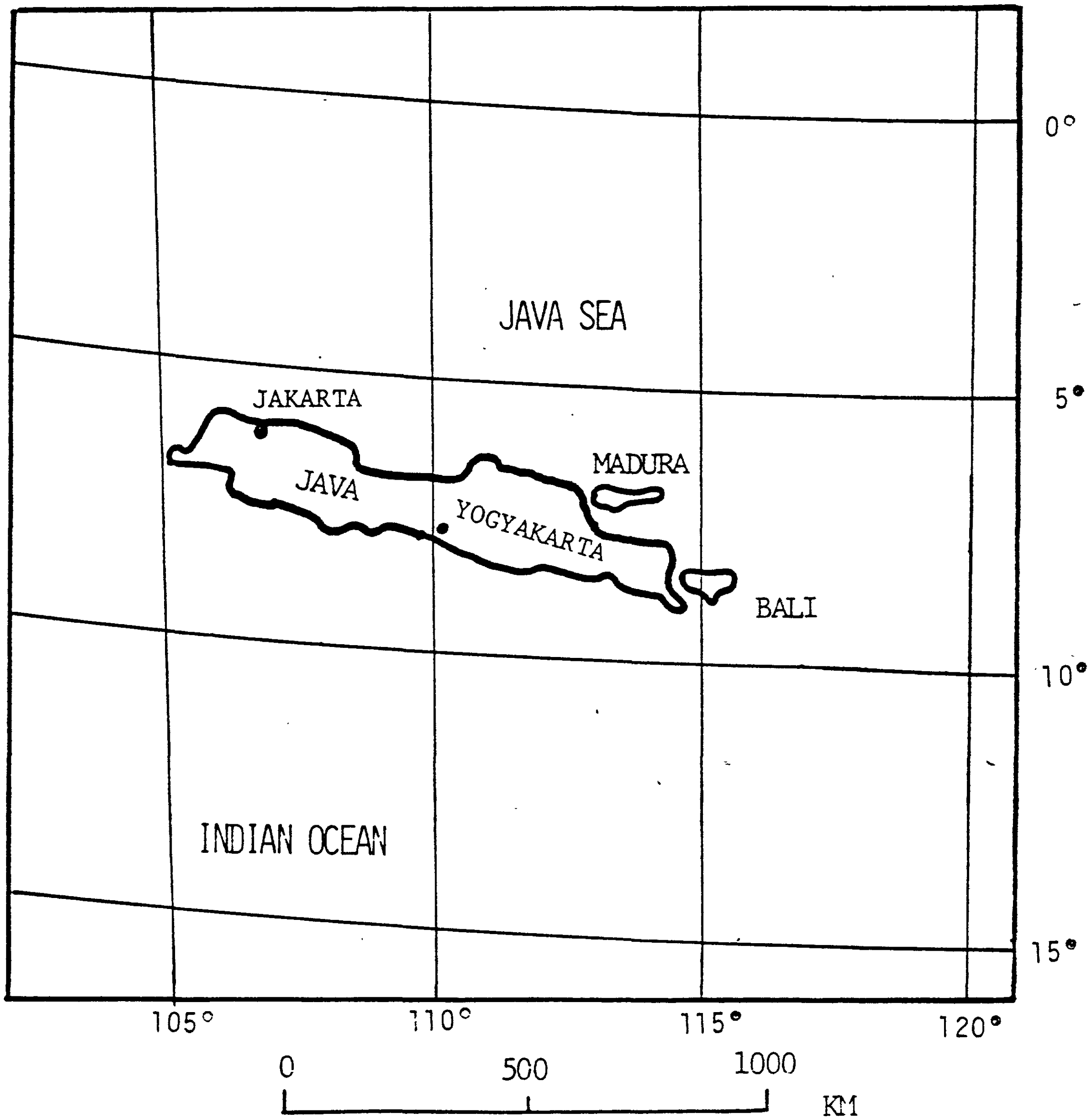

Figure 1. Location of investigation site near Yogyakarta, Central Java, Indonesia.

Where we observed it, the Krasak River channel is broad, has sharp meanders, and, at the time of inspection, was dry. The channel walls are low, 3-4 m above the riverbed. Locally, levees have been constructed that are faced with about 30-40 cm of concrete, and sections are reinforced with gabion walls and concrete blocks. Upstream (east) 2.6 km from a sharp bend in the river channel is a steel bridge, with concrete abutments, that connects the major highway leading north from Yogyakarta. The riverbed at this location is composed of alluvial deposits of clay, sand, and gravel and lahar deposits of volcanic pebbles, cobbles and boulders in a sand-silt-clay matrix.

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Two obvious questions arise concerning the hazards that might result from a lahar or debris flow at this location: (1) could a debris flow overtop the riverbanks and levees and inundate villages and farmland in the adjoining flood plain, and (2) could the debris erode the riverbanks, levees, and bridge abutments, bringing about massive slope and foundation failures? A logical approach to an investigation of potential lahar hazards would be to (1) compile an in-depth history of the size and effects of previous lahars by reviewing existing reports and interviewing local government personnel and residents, (2) investigate the extent and number of old lahar deposits, and (3) consider a lahar in terms of simple-flow mechanics.

We recommend that initially a questionnaire be distributed that would yield information on when lahars had occurred in the past; the weather conditions prior and during the flow; earthquakes and eruptions preceding the flow; whether debris overtopped the riverbanks; erosion or other damage to the riverbanks and engineering structures, and damage to land, houses, and buildings in the flood plain; number of injuries and deaths; loss of livestock and crops; composition of debris material; velocity of debris flow; how much (depth) filling of river channel by debris deposits; and rate of erosion of depositional material by later water and lahar flowage and other natural forces.

A field study to gather basic data on past lahar events for application to engineering solutions should follow the interviews based on the questionnaire. We suggest that it would be beneficial to investigate the number, extent, and characteristics of old lahar deposits outside the Krasak River channel in the vicinity of Yogyakarta. Mapping the distribution and frequency of past lahars that have overtopped levees will show (1) how often this has happened, if the deposits can be dated; (2) where overflow of levees has occurred in the past, and, therefore, where it is likely to occur in the future; and (3) the nature, thickness, volume, and texture of lahars that have caused problems at various locations in the past.

An analysis of historic lahar events and physical data obtained from field investigations will provide information on which to construct lahar-flow models, and areal extent of potential hazards in the locale near Yogyakarta. This information can be applied to land-use planning and the design and location of remedial- and protective-engineering structures.

In designing engineering structures and hazard-mitigating procedures, one must accept the obvious fact that force (gravity) and mass (debris particles) cannot be controlled in a debris flow. The one factor that may yield somewhat to engineering design is velocity. If the velocity is decreased, there is a corresponding decrease in force, kinetic energy, work, momentum, and impulse. This suggests that in critical areas along the Krasak River, a variety of engineering procedures might be initiated that would cause a drop in velocity of a coursing-debris flow, and thus decrease its destructive potential.

Slowing down a flow in these critical areas might be accomplished by several means. Some possibilities include (1) widening the flow channel, (2) flattening the channel gradient, (3) increasing the flow length by constructing diversion channels and (4) installing baffles perpendicular to the flow. Any method of decreasing velocity, however, has the accompanying reaction of load dropping and filling of the channel with debris. This means that constant maintenance of the channel, probably periodic dredging of deposited material from the channel, would have to become part of the control procedure. The dredged material could be, in turn, utilized for constructing protective levees along the river channel. In addition, engineering structures impacted by debris would be damaged and would require frequent repairs.

Overtopping of levees by lahars is a threat to villages, farmland, and engineering structures and is a function of volume of material, available space for the material (channel cross section), and the ability of the flow material to ride over banks or barriers (momentum). The overtopping problem may be lessened by the procedures mentioned above, that is (1) increase the space available for flow debris by widening and deepening the channel or increase the flow area by constructing additional channels, and (2) decrease the velocity by lowering the gradient and introducing flow barriers.