June 23, 2006

Central Java Earthquake Assessment of Rehabilitation and Reconstruction Needs

Report of Survey on the Prevention of Secondary Disasters (Sediment-related Disaster Planning)

Haruo NISHIMOTO, Director for Volcanic Sabo and Debris Flow Control
Sabo Planning Division, Sabo Department
Ministry of Land, Infrastructure and Transport
Tomoyuki NORO
Long-Term Specialist (sabo engineering) dispatched by JICA
Wataru SAKURAI, Senior Researcher
Erosion and Sediment Control Research Group, Public Works Research Institute
Munehiro MATSUI
Director of the Integrated Disaster Prevention Department, Sabo Technical Center

1. Introduction

On May 27, an earthquake with a magnitude of 6.3 on the Richter scale hit Central Java, Indonesia, which caused considerable damage in the Bantul District, south of Yogyakarta, and the large surrounding area including the outskirts of Yogyakarta, where collapse of houses claimed the lives of more than 5,000 people.

In addition, volcanic activity of Mount Merapi, which is located about 30 km north of Yogyakarta, has been observed for the first time since 1994 and a pyroclastic flow has been confirmed to reach a point 5 km from the crater as of June 9. The continued strong activity raises fears of large-scale mudflows in the rainy season.

For the purpose of assessing the condition of damage caused by the earthquake and the needs of the Indonesian government and presenting suggestions for the prevention of secondary disasters that may be induced by the earthquake and volcanic activity, the Japan International Cooperation Agency dispatched an investigation team for activities schedules from June 5 to 14. The authors present in this report the results of the investigation into the actual situation of the affected areas from the viewpoint of the prevention of sediment-related disasters and the suggestions for preventing possible sediment-related disasters.

2. Schedule

June 5	Narita 11:35 - Yogyakarta 20:35
June 6	Meetings at the Embassy and JICA office (by NISHIMOTO and other members on the investigation team) Survey of the slope failures caused by the earthquake in the mountain terrain east of the Bantul District (by NORO, SAKURAI and MATSUI)
June 7	Survey of the slope failures caused by the earthquake in the mountain terrain east of the Bantul District (Bantul, Sleman and Gunungkidul Districts) Opinion exchange with Professor Dwikorita of Gadjah Mada University

June 8	Field survey of the volcanic activity at the base of Mount Merapi
June 9	Information gathering about the volcanic activity at the Merapi Volcano Observatory of the Ministry of Energy and Mineral Resources and survey of the slope failures caused by the earthquake in the mountain terrain east of the Bantul District (Bantul, Gunungkidul and Klaten Districts)
June 10	Field survey of the slope failures caused by the earthquake at the base of Mount Merapi with Mr. Yoneda, the leader/Deputy Director General, Southeast Asia Department of JICA (by NISHIMOTO and MATSUI) and report writing (by NORO and SAKURAI)
June 11	Report writing
June 12	Briefing to the Local Government of DI Yogyakarta and other organizations on sediment-related disaster control measures at the BAPEDA (attended by the BAPEDA (Regional Development Planning Board), DINAS (Public Works Department) and Local Governments of DI Yogyakarta and Sleman)
June 13	Briefing to the Embassy on the investigation results and measures required Briefing to the Director General of Water Resources, Ministry of Public Works on the investigation results and measures to be taken Opinion exchange with the Head of the Ministry of the Geological Agency, Energy and Mineral Resources about measures for volcanic disaster control
June 14	Jakarta 0:25 - Narita 9:35

3. Personal meetings

Meetings were held with the following people during the investigation period for opinion exchange and information gathering as well as reporting on the results of investigation.

	Name	Affiliation/title
1	Ir.Siswoko, Dipl.HE	Director General of Water Resources of the Ministry of Public Works
2	Ir. IMAM MARDJIANTO, Dipl. HE	Manager of the Merapi Sabo Construction Office of the Ministry
3	Ir.Hariyono Utomo	Director of the Sabo Technical Center of the Ministry
4	Bambang Dwiyanto, M.Sc	Head of Agency of Geology of the Ministry of Energy and Mineral Resources
5	Ir.Suyartono, M.Sc.	Secretariat of the Ministry
6	Dr.A.Ratdomopurbo	Head of the Merapi Volcano Observatory of the Ministry
7	Drs Subandriyo Msi	Head of the Mount Merapi Section of the Ministry
8	BAYUDONO	Head of the Regional Planning Board of DI Yogyakarta
9	Dr.Ir.Sunjoto, Dip.HE, DEA	Deputy for Facility and Investment of DI Yogyakarta
10	Dwikorita Karnawati, M. Sc., Ph.D.	Professor at Gadjah Mada University (geology)
11	Dr.Ur.Subagyo Pramumijoyo	Professor at the University (geology)
12	Ir.Djoko Legowo Dipl. HE	Former Head of the Aceh Province Section of the Directorate General of Water Resources Eastern Regional Bureau, former Director of the VSTC
13	Ir.Kusdaryono Sutosuromo	Former aide to the Minister of Public Works

4. Overview of the earthquake

The earthquake occurred at 5:53 a.m. on May 27, with its epicenter in southern Bantul District at a depth of 33 km. The magnitude was 6.3 on the Richter scale and the presumed cause of the earthquake is the horizontal sinistral displacement of the earthquake fault in eastern Bantul District.

This earthquake caused extensive damage including 5,738 deaths, 48,873 completely destroyed and 118,714 damaged houses. (The death toll of the victims was released by the National Disaster Management and Refugee Coordination Agency on June 8 and the building damage by the Ministry of Social Welfare on May 31.) Damage to houses was studied on site, which showed that most of the ordinary houses had a structure with walls of bricks laid with poorly mixed concrete topped with a roof of logs of a few centimeters square covered with tiles and were structurally highly vulnerable to earthquakes (Photo 4.2). The tiles broken to pieces due to the collapse of houses were often found, suggesting extremely low strength.

Photo 4.1: Damage to houses caused by the earthquake (Bantul District)

Photo 4.2: Wall structure: bricks laid with muddy mortar

There is almost no doubt that the collapse of these houses that were structurally very vulnerable to earthquake motions added to the damage. Damage to other buildings such as hospitals and schools was also serious. On the contrary, damage to civil engineering structures such as roads and bridges was minor and no utility poles were found fallen even in areas that suffered massive collapse of houses. The development of and strict adherence to anti-seismic standards of building structures is necessary.

While damage in the Bantul District has been often reported, affected areas spread extensively along the mountain range extending northeast from the Bantul District and the collapse of houses at the base of the mountains was especially serious. This is considered to be due to the extensive activity of the earthquake fault that runs along this mountain terrain.

5. Investigation results

5.1 Condition of damage caused by the earthquake

5.1.1 Local situations

The study of the slope failures caused by the earthquake was conducted in an area extending from around the epicenter in the Bantul District to the borders between the Bantul, Sleman and

Gunungkidul Districts in the mountains east of the Bantul District, which were presumed to have suffered the slope failures because of the closeness to the epicenter (Figure 5.1).

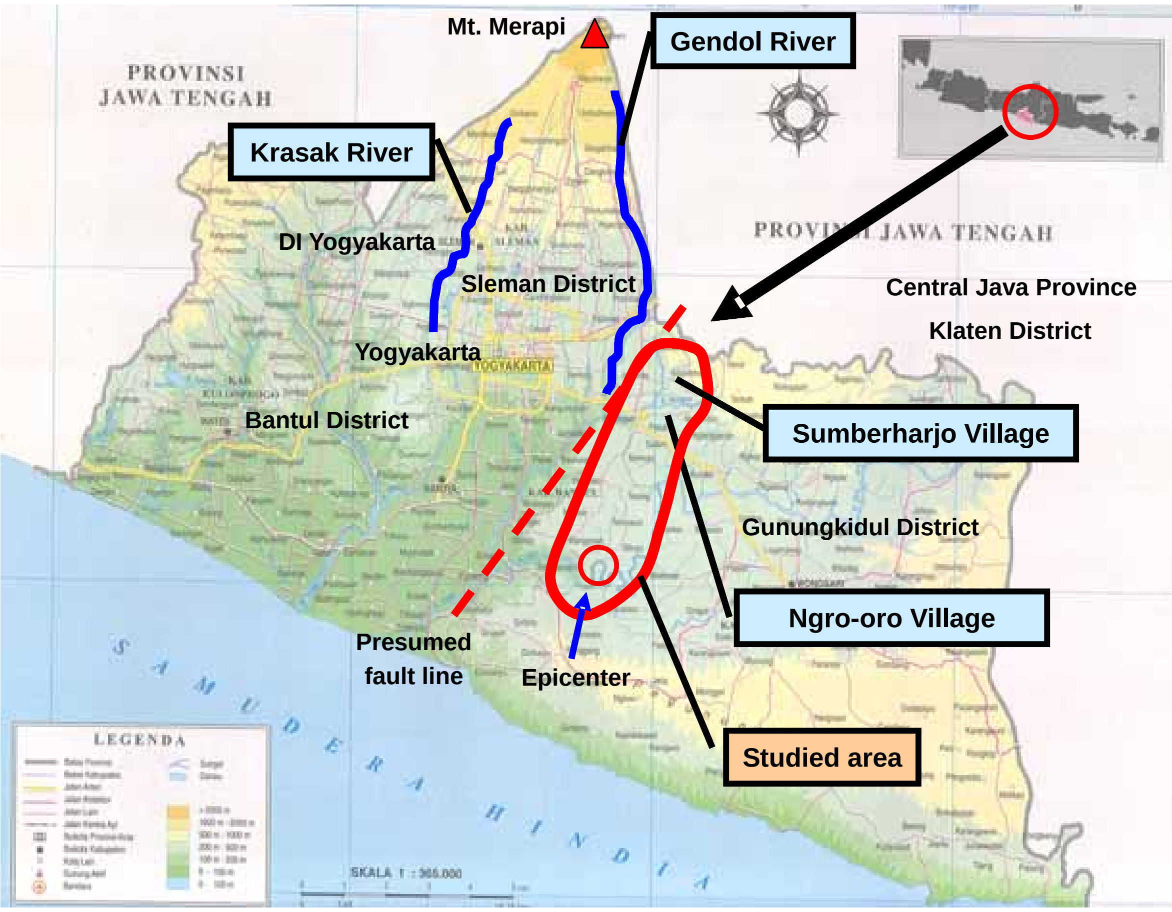

Figure 5.1: Studied area

This mountain terrain extends northeast about 30 km from the southwestern part of the Bantul District, bends in the shape of an L along the borders between the Bantul, Sleman and Gunungkidul Districts and goes on to run eastward (Figure 5.2).

The topography can be described as hilly mountains of about 500 m above sea level. While the slopes facing northwest or north make cliffs (on the Bantul and Sleman side) that fall into a plain stretching from Yogyakarta, the slopes facing southeast to south that are on the other side (on the Gunungkidul side) are gentle inclines, which make a cuesta topography (Figure 5.2, Photo 5.1).

Regarding the geological condition, the Bantul and Sleman side has prominent tuffs and tuff breccias and the Gunungkidul side, the opposite slope, is composed mostly of limestone. At the base of the mountain on the Bantul and Sleman side, the earthquake fault presumed to have been active in the earthquake is considered to extend from northeast to southwest.

The field study conducted includes the assessment of the distribution of slope failures in the area along the mountain range starting from the epicenter, damage caused by the slope failures and characteristics of the failure hazard area. This study has been a rough one for presenting suggestions to prevent secondary disasters after the earthquake and extensive investigation including detailed measurements of the individual hazard areas have not been made due to the time constraints. For this reason, the result shown here is at a level of understanding of the overall condition mainly by visual observation. More detailed study is considered required in the future for the identification of areas subject to secondary disasters and the understanding of the characteristics and tendencies of the failure hazard areas.

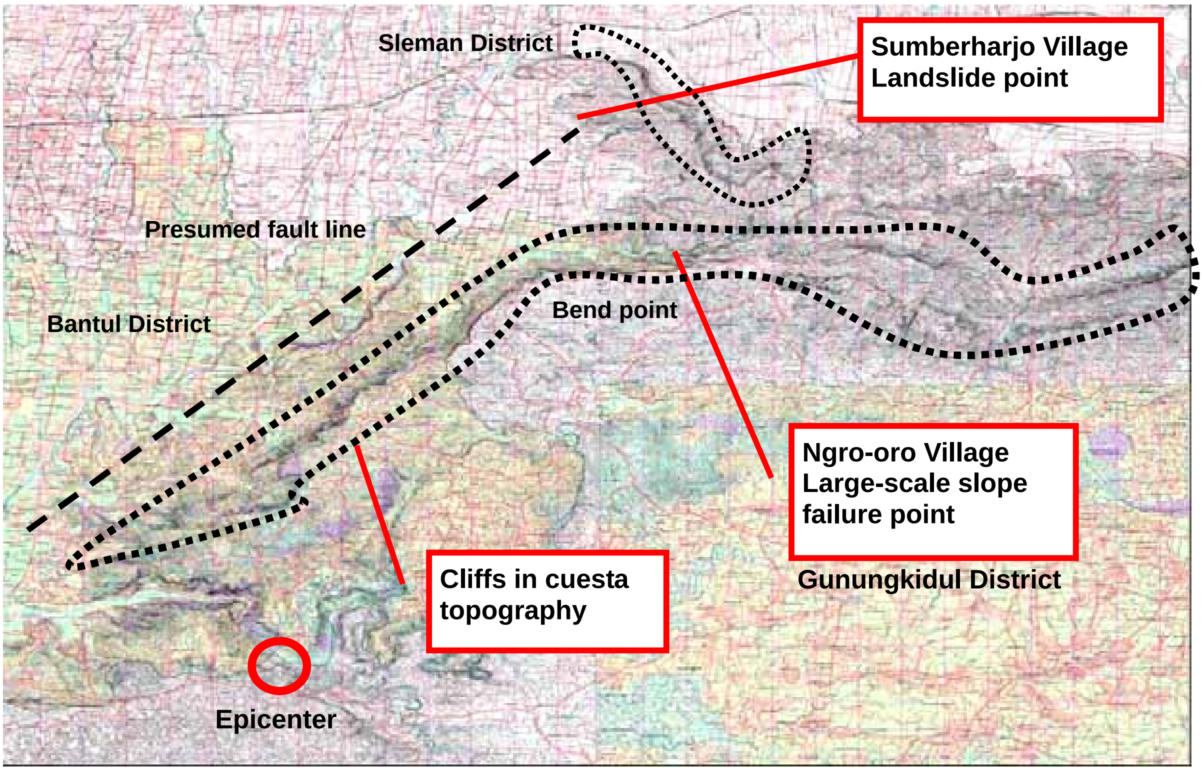

Figure 5.2: Mountain topography overview
(fault line roughly indicated based on Kompas June 3, 2006)

Photo 5.1: Cliffs in the mountain terrain studied

As a result of the study, failures have been observed all over the hillside near the epicenter and on the slopes facing northwest and the opposite slopes facing southeast in the mountain terrain around the Bantul District, which suffered serious damage caused by the collapse of houses (Photo 5.2).

Photo 5.2: Failures in the mountains east of the Bantul District

The slope failures have been often found on the convex slopes or along the knick lines in the upper parts of cliffs in the cuesta topography and are mostly surface or rock failures. This is apparently in accord with the characteristics of quake-caused failures that have been traditionally presented. On near-vertical cut slopes along the roads, walls of terraced paddy fields and slopes of residentially developed land, numerous small-scale failures have been found.

Photo 5.3: Failures on cliffs

Photo 5.4: Failures in series

The slopes facing north in the vicinity of the borders between the Bantul, Sleman and Gunungkidul Districts about 20 km north-northeast of the epicenter, where the mountain terrain bends eastward, have many failures on cliffs of the cuesta topography (Photo 5.3). In the Jatikuning area of Ngro-oro Village, Gunungkidul District, in particular, large-scale failures have been found (Figures 5.1, 5.2). These failures have occurred at intervals in an area of about 700-800 m wide from the knick lines at about 320-330 m above sea level on the series of near-vertical cliffs in the east-west direction of about 100 m in relative height on the north slops of the mountains (Photo 5.4). They are rock or surface failures, which are likely to have been caused by the collapse of the bedrock in blocks from the joint due to the earthquake motion. The geology seems to be mostly tuff breccias in strata of opposite dip. Immediately below the slopes are sediments of rocks of about 4-5 m and the collapsed soil has been deposited immediately below the slopes in spite of the relative height of about 100 m. This is presumed to be because of the low moisture content of the soil due to the dry season, which spared the houses below the slopes of direct hit of the collapsed soil. However, unstable, overhung banks and large masses of rocks still remain (Photo 5.5) and numerous cracks are found in the fields in the upper part of the slopes or on the neighboring slopes (Photos 5.6, 5.7), which indicates an extremely high possibility of larger-scale collapse in the rainy season. Despite the danger posed by these conditions, residents still remain in a settlement directly under the slopes (Photo 5.8).

In the Pandeyan area of Semoyo Village, Bantul District, located about 5-6 km southwest of these slopes, rock falls have caused one death (Photo 5.9) and damage to a house (Photo 5.10).

Photo 5.5: Collapsed soil in unstable conditions

Photo 5.6: Crack on slope

Photo 5.7: Cracks found in field on plain in the upper part of slope

Photo 5.8: Settlement below overhung collapsed slope (about 100 m high)

Photo 5.9: Site of fatal rock fall

Photo 5.10: House damaged by rock fall

In the Nglepen area of Sumberharjo Village, Sleman District, about 3 km north from the slope failure hazard area of Jatikuning, the earthquake has caused a large-scale landslide (Photos 5.11, 5.12).

While the slope failures have occurred on the cliffs on the north side of the cuesta topography, this landslide has occurred on the gentle slopes on the south side. The surrounding topography is in a horseshoe shape and the earthquake is considered to have reactivated old landslides. The geology can be characterized by alternate layers of mudstones and tuffs and is presumed to be a dip slope based on the conditions of the bare rocks in the surrounding area. With the sliding surface unexposed, however, the properties or location of the sliding surface have not been identified. The scale of the landslide is about 160-170 m in scarp width, 5-6 m in scarp height and 160 m in entire length of landslide block. In addition, a depressed topography of 30-40 m wide has been generated along the scarp, into which a few houses have been found fallen to be completely destroyed (Photo 5.12).

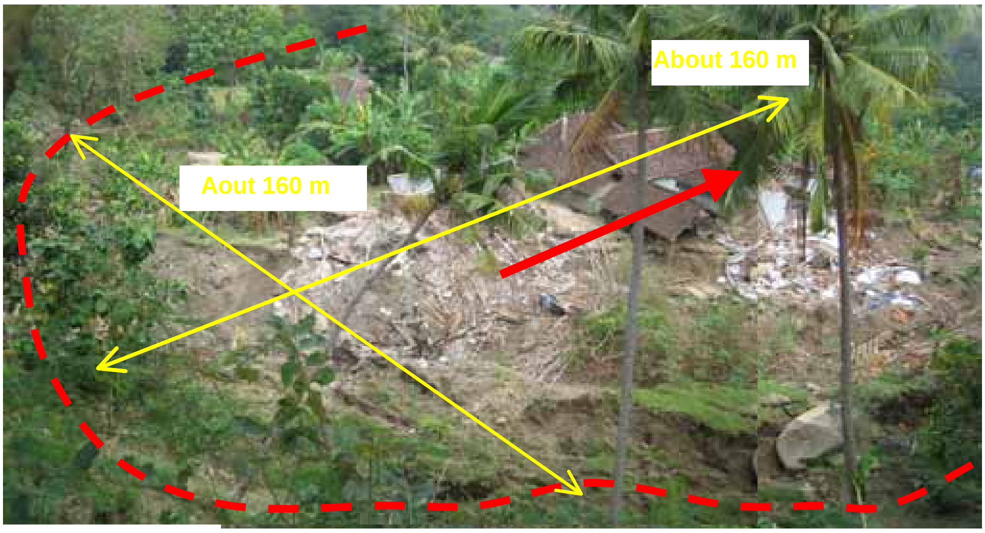

Photo 5.11: Landslide area seen from the upper part of the scarp

Photo 5.12: Situation of the landslide area

Although all of the 13 houses in the landslide area have been damaged, six of which completely destroyed, fortunately nobody has been killed or injured. However, resettlement is difficult and all of the residents are reportedly planning to relocate. Based on the interviews with villagers, the landslide occurred immediately following the earthquake, which caused the soil to slide approximately to the current position and continue to be displaced for about ten minutes. No water discharge, etc. has been found as of the time of the investigation and there is little possibility of abrupt slides anytime soon but many cracks have been observed in the landslide area (Photo 5.13), which indicates high risk of further displacement in the rainy season. In addition, the distal end of the landslide has extruded towards the valley, posing danger of blocking the river channel (Photo 5.14). This may break and flow down as a mudflow to the settlements downstream in the rainy season, causing damage.

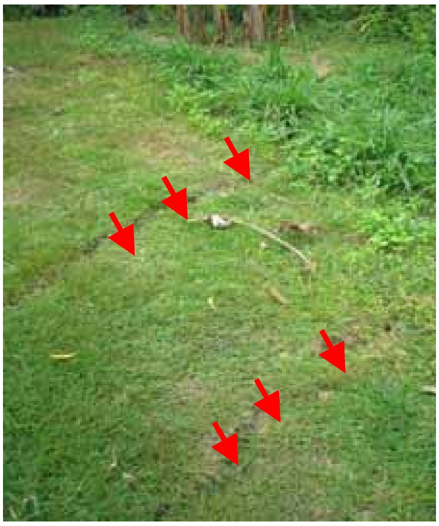

Photo 5.13:
Cracks in a landslide area

Photo 5.14: Distal end of landslide area

Furthermore, a series of cracks of about 100 m in total length has been found in the flatland (fields) above the knick lines of the cliffs in the Pantuk area in the upper part of the mountains in the vicinity (Photo 5.15). On the lower part of the slope is located the Pereng area with about 90 households. The residents of the settlement are not informed of the cracks in the upper part or the hazardous condition and not aware of the danger.

5.1.2 Investigation summary

The human damage due to slope failures or landslides caused by the earthquake in question has been minor. However, unstable banks remain including the numerous cracks, overhangs, etc. on the upper part of the slopes, which strongly suggests the existence of unconfirmed cracks, and there is extremely high risk of sediment-related disasters in the rainy season. In spite of the danger, residents living in the vicinity of the slopes are not fully informed of danger spots and not sufficiently aware of the risk. Apparently, the local governments have not made special effort to conduct surveys of slopes or provide information for the residents. This region does not have experience of sediment-related disasters caused by earthquakes and the residents as well as the local governments seem to have little knowledge about the risk of sediment-related disasters that may follow earthquakes.

Photo 5.15: Condition of cracks

To sum up the characteristics of the slope failures caused by the earthquake, while failures near the epicenter have been minor in extent regardless of the short distances from the epicenter, a number of large-scale failures have been confirmed on the slopes facing north to northwest and landslides on slopes facing south along the borders between the Bantul, Sleman and Gunungkidul Districts about 20 km away from the epicenter (Figure 5.2). Slope failures have tended to be observed more often on steeper slopes and many failures have been found on near-vertical cut slopes along roads and residentially developed land, which points to the possibility that failures selectively occurred on slopes that were originally steep and unstable. The failures are either surface or rock failures in blocks that have occurred on convex or parallel slopes, which agrees with the characteristics of failures caused by earthquakes that have been conventionally mentioned.

5.2 Activity of Mount Merapi

5.2.1 Investigation results

Mount Merapi, which is located north of Yogyakarta, has shown strong activity for the first time since 1994 as characterized by the first pyroclastic flows on May 13. On June 4, a lava dome collapse caused large-scale pyroclastic flows, which the Merapi Volcano Observatory of the Ministry of Energy and Mineral Resources estimates have produced about 400,000 m3 of sediment. Extensive pyroclastic flows occur almost daily (Photo 5.16) and the Observatory says as of June 9 that the flows have spread 5 km from the crater, forcing the evacuation of residents living in an area within 7 km from the crater.

Photo 5.16: Pyroclastic flows into Gendol River

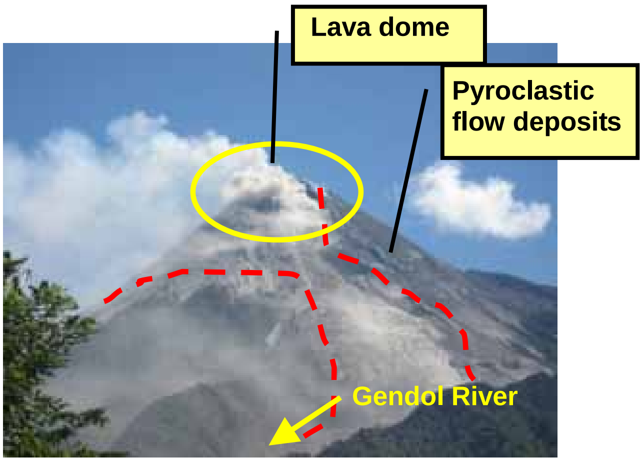

Photo 5.17: Mountain slopes

The Observatory also says that the lava dome continues to grow at a pace of about 170,000 m3 a day and its scale has reached about 4 million m3 (as of June 9). According to the information provided by the Observatory as of June 12, the total volume out of the spout is 6.5 million m3, the volume accumulated around the lava dome near the peak about 3 million m3 and the volume that has flowed down as pyroclastic flows 3.5 million m3. The Observatory's assumption based on the past records is that volcanic activities may continue for about one year, which suggests the possibility of further deposition and flow-down of unstable volcanic products. This poses a concern for large-scale mudflows in the rainy season. In the meantime, the Directorate General of Water Resources estimates that the available capacity of the sabo facilities at the base of Mount Merapi is about 9.1 million m3 in total. Future continuation of the volcanic activity is likely to cause accumulation of volcanic products that exceeds the capacity, which calls for measures including emergency debris removal.

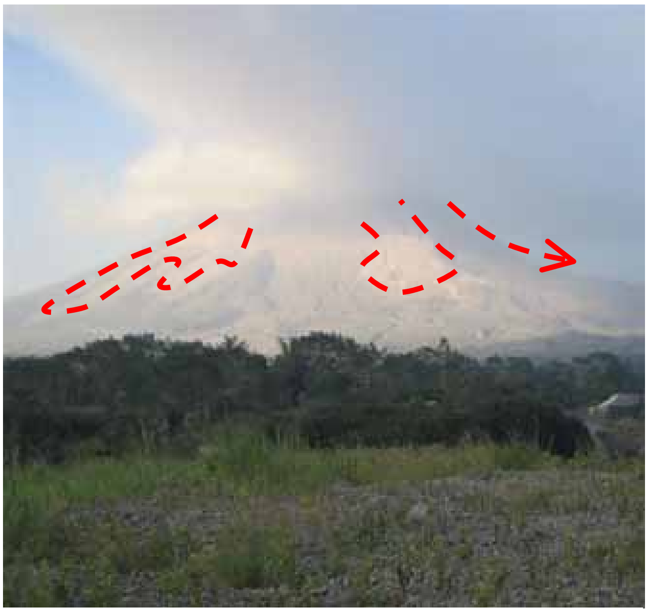

Photo 5.18: Directions of pyroclastic flow deposition: Blongken River on the left side, Kuning and Boyong Rivers on this side and Gendol River on the right side

As a result of on-site visual observation of the spread of the pyroclastic flows, the flow-down towards Gendol River is prominent (Figure 5.3) and the distance of flows is longer than for any other rivers at about 5 km, or about 1,200 m above sea level. In addition, the accumulation of the pyroclastic flow deposits in three directions has been reported: towards Boyong, Kuning and Blongken Rivers (Photo 5.18). This causes the risk to rapidly grow of the increase of pyroclastic flow deposits due to the flow-down and of massive mudflows caused by possible erosion of the deposits in the rainy season along these rivers.

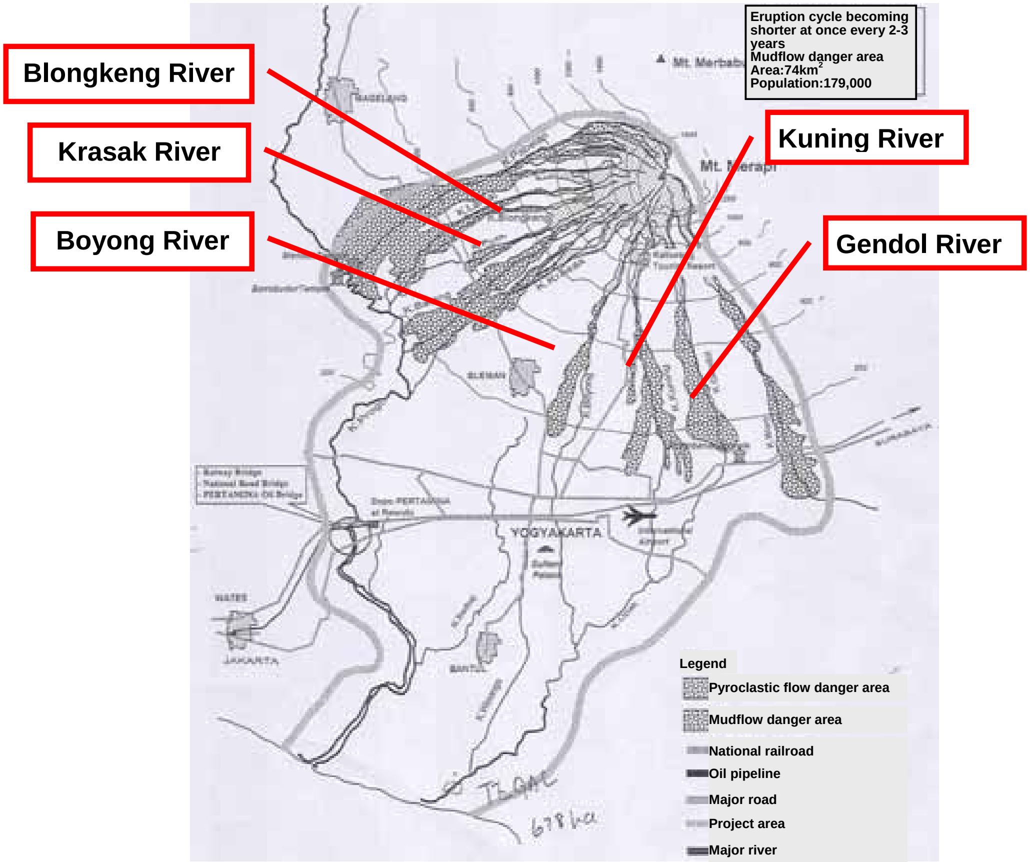

Figure 5.3: Rivers around Mount Merapi

After our study has been completed, a large-scale pyroclastic flow towards Gendol River occurred on June 14 that reached a point 7 km away from the crater (1,000 m above sea level) causing two deaths and a heavy pyroclastic flow deposited in Gendol River as well (Photo 5.19). Although the deposition thickness has not been accurately identified, the deposition distance from the crater points to a considerably large volume of pyroclastic flow deposits. This heavy deposition of pyroclastic flows in the river channels increases the risk of massive mudflows in the rainy season.

Photo 5.19: Pyroclastic flow deposits in Gendol River (source: Sabo Technical Center, Directorate General of Water Resources, Ministry of Public Works)

6. Measures required for the prevention of secondary disasters caused by the earthquake and volcanic activities

6.1 Measures for preventing secondary disasters following the earthquake

The earthquake in question has only caused minor human damage due to slope failures and landslides but many cracks and unstable banks have been found in the upper part of the slopes, which suggests a strong possibility that there are more cracks unidentified and extremely high risk of sediment-related disasters in the rainy season. The district or provincial governments and people living near the slopes are not fully informed of the danger spots and not well aware of the risk. In the landslide area in Sumberharjo Village, precipitation expected in the rainy season supplied to the landslide block through the cracks may activate the soil displacement and, in the worst case, block the river channel below the distal end of the landslide. For this reason, the following measures must be immediately taken:

1) Slopes that may cause further sediment-related disasters must be promptly identified and the residents informed of the danger spots. In particular, many failures have occurred and numerous cracks have been found on the cliffs of the slopes near the borders between the Bantul, Sleman and Gunungkidul Districts and the slopes in this area with any settlement directly below them must be studied immediately. Other slopes also require inspection for cracks especially on cliffs.
2) Any identified crack must be filled or treated for preventing infiltration of rainwater (by covering with plastic sheets) as emergency measures. In addition, monitoring with instruments such as strain gauges and visual observation, the development of the channel of information to notify the residents of the results, the establishment of the emergency evacuation system, etc. are required.
3) As a result of the study of the slopes, disaster prevention capabilities must be strengthened by providing the residents of settlements at high risk of sediment-related disasters at a community level with disaster prevention education, information about the danger spots and the precursory phenomena, guidance for slope monitoring techniques, clarification on the shelters and evacuation routes, etc.
4) Equipment and measuring instruments required for studying hazardous slopes (strain gauges, etc.) must be provided.
5) Regarding the landslide in Sumberharjo, Sleman District, filling of cracks as an immediate measure for preventing rainfall supply through the cracks to the landslide soil mass and surface runoff draining by temporarily cutting unlined tunnels for preventing flooding of large-scale depressions generated directly below scarps and rainwater infiltration into other cracks are considered required.
6) For carrying out the investigations and measures as described above, it seems required to provide technical assistance from Japan, which has abundant experience with quake-caused sediment disaster control, to Indonesia, which does not have experience of sediment-related disasters caused by earthquakes.

6.2 Measures for preventing secondary disasters due to volcanic activities

In preparation for possible mudslides in the rainy season and for the prevention of future volcanic disasters, the following measures are required:

1) As a preparatory measure for volcanic eruptions, the Ministry of Energy and Mineral Resources have created hazard maps based on the damage records for the past 100 years. However, the conditions of pyroclastic flows and mudflows may very for every eruption and the topography is constantly changing even now and hazard maps must be created as required according to the changes in the actual volcanic activities. For this reason, it is desirable to obtain the capability of quickly acquiring digital altitude data that takes advantage of aerial/satellite remote sensing technologies and to establish warning and evacuation systems based on the prediction of the extent of the impact that uses the acquired data for simulation of pyroclastic flows and mudflows.
2) In rivers with the risk of mudflows, it is necessary to discuss in advance the non-structural measures including emergency debris removal, bank raising and training dike construction by checking the available capacity of sabo dams, dams allowing debris removal, conveyance routes/disposal areas and the points requiring training dikes. These emergency plans must be implemented in preparation for possible mudflows in the rainy season.
3) Regarding the creation of volcanic hazard maps, aerial/satellite remote sensing technologies are becoming effective even in developing countries thanks to the accuracy improvement and cost reduction. The technologies are considered to be applicable in Indonesia as well. Japanese technical assistance appears to be necessary in preparation for the rainy season so that digital altitude data can be acquired and calculations can be made concerning pyroclastic flows and mudflows for the development of effective warning and evacuation systems.

7. Conclusion

The following sections outlines the measures required for the prevention of secondary disasters in relation to the earthquake and volcanic activity. To prevent human damage caused by secondary disasters, the measures mentioned below must be taken immediately:

(1) Measures for sediment-related disasters following the earthquake

1) The mountain terrain about 12-13 km east of Yogyakarta City has suffered a number of landslides and large-scale slope failures. In addition, many areas have been confirmed to have numerous cracks in the upper part of slopes if not collapsed yet, despite the short period of investigation. This has led to an idea that the earthquake is highly likely to have generated many cracks in other areas that have not been studied.
2) Accordingly, the area around the mountain terrain has become more vulnerable to slope failure disasters.
3) It is thus necessary for the responsible administrative agencies to become fully aware that immediate identification of danger spots, notification of the spots to residents, monitoring by installing observation equipment in points with high risk and development of warning and evacuation systems for the rainy season are urgent tasks for protecting the lives of the residents.

(2) Preparatory measures for possible eruption of Mount Merapi

1) Gendol River has been active with the production and runoff of sediments due to frequent pyroclastic flows. For this reason, the risk is greater of future massive mudflows due to the increase of unstable pyroclastic flow deposits and erosion of mountains in the rainy season in addition to damage caused by pyroclastic flows.
2) The pyroclastic flow deposits from Gendol to Krasak Rivers has also been increasing, which poses a danger of large-scale mudflows in the rainy season.
3) For protection of human life, it is important to update hazard maps as required according to the trend of eruption, the result of which must be communicated to administrative agencies and residents.
4) Regarding modification of hazard maps, an accurate understanding of the current topography data and simulation based on the data are necessary to make corrections.

(3) Japanese technical assistance

1) Since Indonesia does not have sufficient knowledge about the measures against sediment-related disasters on slopes after earthquakes, technical assistance by Japan is required from the perspective of urgency and prevention.
2) Regarding the method to create volcanic hazard maps that use digital data on topography, etc. Japanese technical assistance is called for.