CHAPTER EIGHT

CASE HISTORIES

EXAMPLES OF MAJOR MUDFLOW DISASTERS

In this chapter, case histories of several major mudflow events which have occurred around the world in the recent past are presented, as examples which demonstrate the importance of mudflows and their significant impact on human lives, society and the environment. Each event described is different—in its causes, its consequences and in the lessons learned from it, both positive and negative. However, taken together, they demonstrate clearly that mudflows are a real danger—worldwide.

(It is difficult to derive an accurate classification of these events based on their triggering phenomena; therefore, the classification given below is only a simplified approximation made solely for the purpose of this monograph.)

8.1. Mudflows caused by heavy rain, snowmelt and excess water

Gradenbach, Austria, 1965, 1966	rain
Wollinitzbach, Austria, 19.08.1966	rain
Aberfan, UK, 21.10.1966	saturation of mining refuse heaps
Mizusawashinden, Japan, 23.07.1982	snowmelt and rain
Mt. Semeru, Indonesia, 06.05.1981	rain
Nagasaki, Japan, 23.07.1982	rain
Surat Thani and Nakhon Si Thammarat Provinces, Thailand, 1988	rain
Ormoc City, Philippines, 05.11.1991	tropical rainstorm
Palung River Basin, Nepal, 19.07.1993	rain

8.1.1. Gradenbach and Wollinitzbach, Austria (1965, 1966)

Both catchments are characterized by large and deep landslides as well as by huge deposits of moraine which have been discharging sediment during periods of snowmelt and rainfall.

Gradenbach (1965, 1966)

The Gradenbach torrent has a catchment area of 32 km^2 more than two thirds of which consists of rocky slopes. Most of the remaining area is covered with pastures and a small part is arable land. In the upper reaches, there is a glacier. An alluvial cone of 900 m length and 10 per cent slope is situated at the mouth of the 6 km long canyon.

The heavy rainfall of 154 mm in September 1965, and 221 mm in August 1966, caused unprecedented floods. During these two events, the torrent transported altogether 1.3 million m^3 of material to the alluvial cone of the Moell River. The village of Putschall, which was situated on the alluvial cone, was buried (*Fig. 8.1*) and the village of Doellach, situated further down the valley, was heavily damaged. The Moell Valley highway was also destroyed.

The critical section of the Gradenbach torrent is the 900 m long canyon at the end of the catchment. The entire left slope from there up to the ridge has been moving on the order of several decimetres per year due to rock-creep. The slope is virtually waterlogged and is marked by numerous springs. The slope is composed of masses of slate, dolomite and moraine and has been undercut by the torrent. Above the slide scar, it is under cultivation, while further up there is a forest belt ascending to a height of 1,800 m, above which there are bush cover and pasture.

FIGURE 8.1 Putschall village on the alluvial cone of the Gradenbach torrent in the Moell Valley, Carinthia, Austria, buried by floods and debris flows during 1965 and 1966. *Photo: G. Kronfellner-Kraus.*

Wollinitzbach (1966)

The size of the catchment of the Wollinitzbach torrent is approximately 8 km^2 at heights ranging from 705 m to 2,834 m. The middle reaches of the stream are relatively well covered with vegetation (spruce and larch trees) while the slopes of the upper reaches have been used for pasture. In the lower reaches, the torrent has formed a huge alluvial cone.

Following a heavy rainfall of 195 mm on 17-18 August 1966, catastrophic debris flows came down the mountain during the night of 19 August, killing three persons and burying the greater part of the village of Kleindorf (*Fig. 8.2*). About 300,000 m^3 of material came down to the alluvial cone and into the Moell River.

Control works

In the Wollinitzbach region, systematic control measures were begun after the mudflow events described above. They comprised the draining of the terrain around erosion scars (*Fig. 8.3*) in the upper catchment and the diversion of all surface water from the scars by pipes, channels and horizontally-drilled drains. A series of check dams was installed in the stretch of the torrent where erosion was active. An open dam was built at the outlet of the ravine in order to remove boulders and timber debris which threatened the settlement on the alluvial cone. On the alluvial fan, the stream was controlled by training walls and sills.

The control techniques applied in the case of Gradenbach for the restoration of the areas affected by rock-creep included, in particular, the building of check dams and drainage works to prevent further erosion. It would appear that a massive deposit of sediment at the foot of the slope must be awaited before its deep-seated movement can be arrested. This will require time.

Control works and reforestation alone, however, cannot suffice if people continue to occupy dangerous zones. Accordingly, in order to prevent the development of settlements in such zones, the Torrent and Avalanche Control Service has been entrusted with the responsibility for space planning. It publishes hazard maps which provide a basis for better space planning in terms of economy and technology.

8.1.2. Aberfan, United Kingdom (1966)

At about 0915 hours on Friday, 21 October 1966, a huge mass of colliery rubble swept swiftly and with a jet-like roar down the side of Merthyr Mountain, which overlooks the western edge of the coal-mining village of Aberfan in South Wales, United Kingdom. This massive breakaway from a vast tip completely destroyed a school and eighteen houses. Another school and several other dwellings in the village suffered damage. In the disaster, 144 people lost their lives, 116 of whom were children between the ages of 7 and 10 (HMSO, 1969).

Tips are the refuse heaps of the coal-mining industry. The land which was used for tipping sites was generally of low value. The stability of coal tips had, therefore, received scant attention. Those who had expressed fears about the stability of the Aberfan tip had been brushed aside by National Coal Board officials. Others may have entertained doubts about it, but the realization that prohibiting tipping could bring about the closure of the Merthyr Vale Colliery may well have led to the quick

FIGURE 8.2 Kleindorf village built on the alluvial cone of the Wollinitzbach torrent in the Moell Valley, Carinthia, Austria, destroyed by a debris flow on 19 August 1966. *Photo*: *G. Kronfellner-Kraus.*

FIGURE 8.3 Erosion scars in Wollinitzbach, Austria: eroded left bank at Gruberhutte and the mouth of the shell-shaped erosion scar in the background on the right bank. *Photo: G. Kronfellner-Kraus.*

suppression of those doubts; grim memories of long years of widespread unemployment were still vivid in the South Wales valleys.

Investigations showed that Merthyr Mountain consists mainly of fissured pennantite sandstone overlaid by drift material and intersected by layers of relatively impermeable mudstone. One such layer, associated with the Brithdir coal seam, gave rise to a line of springs and was located under tip No. 7, which was one part of the series forming the tip complex on Merthyr Mountain. This tip contained a vast quantity of loosely-tipped, uncompacted material, the lower part of which had become saturated over the years (*Fig. 8.4*). A shear displacement along a surface adjacent to the natural ground, with reduced resistance to sliding, caused the tragic accident.

A pupil who was making his way towards the senior school recalled:

> *At about 9.15 a.m., I heard a sound which to me appeared to be a jet plane screaming low over the school in the fog. I saw a big wave of muck higher than a house coming over the old railway embankment and heading straight towards me. In this muck, I saw boulders, tree trunks, bricks, slurry and water*

The men working at the top of the tip had arrived there shortly before 0730 hours and were above the mist. When the crane driver and a slinger arrived at the top of the tip, they found that it had sunk by about 3 m and that two pairs of rails, forming part of the track on which the crane moved, had fallen into the depression thus created. When two men came at 0900 hours with an oxyacetylene torch to sever the overhanging rails and give instructions for the crane to pull back as far as possible from the sunken position, the top of the tip had sunk another 3 m, so that it was then altogether 6 m below its normal level.

The crane driver described the scene as follows:

> *I was standing on the edge of the depression. I was looking down into it and I couldn't believe what I saw. It was starting to come back up. It started to rise slowly at first. I still did not believe it, I thought I was seeing things. Then it rose up at a tremendous speed, came up out of the depression and turned itself into a wave which rushed down into the mist towards Aberfan village.*

8.1.3. Mizusawashinden, Japan (1969)

The Niigata region of northern Japan is notorious for heavy snowfall. April is the snowmelt season. During the period 21-24 April 1969, an unusually hot air mass resulted in a quick snowmelt. In addition, a drizzle started on 24 April and a total of 19 mm of rain fell on 25 April. At 0730 hours on 26 April 1969, in Mizusawashinden village in Niigata Prefecture, a landslide overran a paddy-field which was filled with snowmelt water (*Fig. 8.5*).The onset of the landslide was heralded by a sound resembling that of a moving bulldozer or a jet plane. The resulting mudflow continued for about 600 m and dammed up the Koyagara River. Eight people were killed and ten houses were buried The flow velocity was estimated as 4.1 m/sec, based on the interval between the start of the sound and the arrival of the flow in the village. After the event, a large quantity of water was released from under the scarp left by the slide The source area can be divided into three topographical parts:

- (*a*) The highest part of the area was oval in shape. The edge coincided with the upper limit of a potential landslide block which could be identified on aerial photographs taken before the slide;
- (*b*) In the middle sector, material which had slid down passed through a long, narrow and steeply-dropping gully, 50 m wide and 200 m long;
- (*c*) The bottom sector formed a natural dam, 5 m high, 110 m wide and 300 m long

It was later found that the paddy-fields had been developed without any attention having been paid to landslide hazard. The stability of the slopes in the upper and middle sectors had not been taken into account. Some precursor phenomena were identified. According to farmers, a crack 100 m long and 30 cm wide had appeared on nearby Mt Mizusawa on 24 April. The next day it was 200 m long and 1 m wide. Farmers were happy to note that the discharge of a spring had increased, so they would have sufficient water to start cultivating their paddy-fields. However, nobody was aware of the fact that all of these phenomena were actually precursor activity

8.1.4. Mt. Semeru, Indonesia (1981)

Mt. Semeru, also known as Mt. Mahameru, is located in the eastern part of Java Island (*Figs. 8.6* and *8 7*) It rises to an elevation of 3,676 m and is the highest active volcano on the island. Mt. Semeru was not always active, however. The prolonged activities of 1855 to 1913 were followed by a long period of quiescence. As a result, people began to settle in the lahar-devastated areas. The population density around Mt. Semeru is 488 per km^2.

In 1981, it rained for seven consecutive days beginning on 6 May and it was pouring steadily on 12 May. Although it was only 1900 hours, most residents of Sumberurip village, situated on the right bank of the Tunggeng River to the east of Mt. Semeru (see *Fig. 8.7*) were already asleep after a hard day's work. Suddenly, a roaring noise was heard which gradually grew louder. The population had never expected a mudflow from the shallow and narrow Tunggeng River, which had never flooded in recent memory. It should be noted that the rainfall intensity had not been particularly high until a few hours before the onset of the disaster. It is assumed, therefore, that the torrential rainfall might have triggered a landslide which mobilized the pyroclastic deposits on the mountain slope. Alternatively, it might have breached a natural dam which could have been formed by a landslide at a higher reach of the river. No precursor phenomena were observed since the higher slopes of the volcano were always covered with thick clouds.

When the mudflow hit in 1981, no one had time to strike a tong-tong, a wooden gong-like device used to give lahar warnings (*Fig. 8.8*). Even if a tong-tong had

FIGURE 8.4 Aberfan, South Wales, United Kingdom. A huge mass of colliery rubble lies on the western edge of the coal-mining village. (Courtesy: Times Newspapers Ltd)

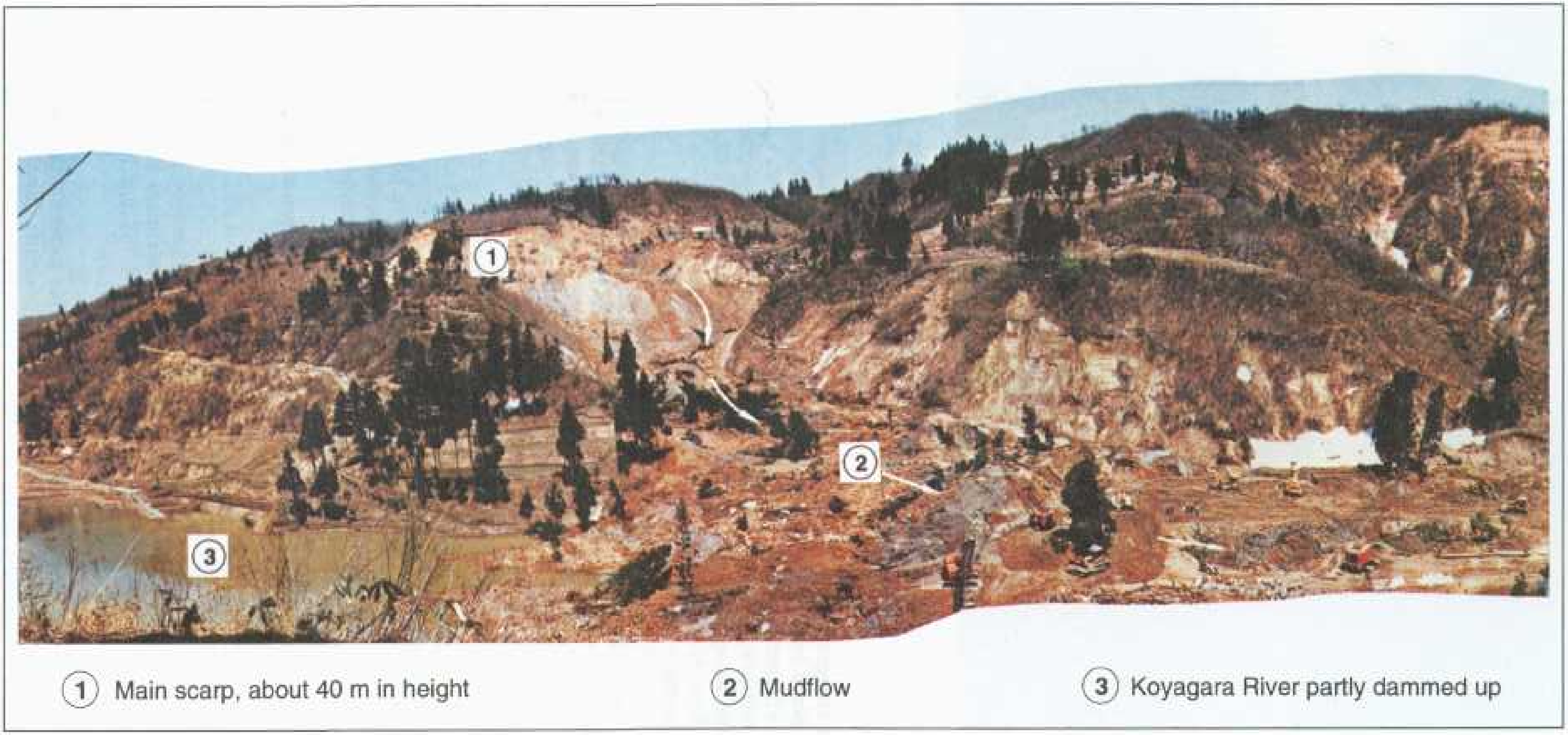

FIGURE 8.5 General view of the Mizusawashinden landslide of 26 April 1969, in Niigata Prefecture, Japan. *Photo: Niigata Prefecture Government.*

FIGURE 8.6 Mt. Semeru, East Java, Indonesia: Two major gullies can be seen on the left and at the centre. A number of rills incise the slopes between gullies. The landslide which triggered the mudflow occurred in the jungle on the right. *Photo: I. Suryo.*

been sounded in other villages higher up in the valley it would not have been heard because of the noise of the downpour. When the villagers realized that they were being invaded by a mudflow, it was already too late. Those at the edge of the village managed to flee southward to safety, but those living near the river were trapped. A survivor who had saved himself by climbing a tree reported that successive surges with a maximum height of about 1.5 m swept through the village, leaving a deposit of mud in their wakes. The mudflow killed 369 people and injured 152. A similar phenomenon had occurred there in 1909. At that time, however, there was not a single village situated along the Tunggeng River and therefore almost no one had witnessed the event.

A huge volume of loose material was deposited along the Tunggeng River following the 1981 mudflow. As this natural phenomenon had occurred during the rainy season, the responsible officials were concerned about a possible recurrence. The vulnerability of an area to lahars depends on the mode of volcanic activity and on the location of the river channel. The middle reaches of the rivers on the south-east flank of the mountain are characterized by frequent changes of channel because of heavy sedimentation. The eastern flank of the mountain was once threatened by the Semut River. Because of silting due to the deposit of pyroclastic material, the Semut River altered its course and joined the Lengkong River (see *Fig. 8.7*).

Structural measures for flood prevention had been taken by the Netherlands colonial Government from the beginning of this century, in particular along the Sat River which previously flowed through the city of Lumajang. However, frequent floods undermined the structures, so that the Government was repeatedly obliged to rebuild, heighten and lengthen the dykes. Another effort to protect the people from lahars was the construction of artificial hills on which they could take refuge.

In 1977, the Semeru Volcanic Control Project was launched. The project was responsible for the building of a series of four check dams prior to the 1981 mudflow on the Sat River which were built to minimize the lahar hazard. The uppermost and lowermost dams were slightly damaged by the flow.

A small radar-based rain-monitoring system and telemetered rain-gauges were installed by 1990. For lahar warnings to the public, loudspeakers are now used. Seismographs have proved to be useful for lahar detection, and were in position by 1990. The onset of a lahar is immediately recorded and a timely warning can be given.

8.1.5. Nagasaki, Japan (1982)

A total of 572 mm of rain fell on Nagasaki, Japan, on 23 and 24 July 1982, a record in the history of the Japanese Meteorological Agency. This localized downpour had a maximum intensity of 127.5 mm/hr in Nagasaki city and 187 mm/hr in neighbouring Nagayo township (*Fig. 8.9*).

This torrential rain caused flooding, and a large number of debris flows and slope failures in the Nagasaki region (*Fig. 8.10*). Nagasaki, once the victim of a man-made disaster as the target of an atomic bomb, was this

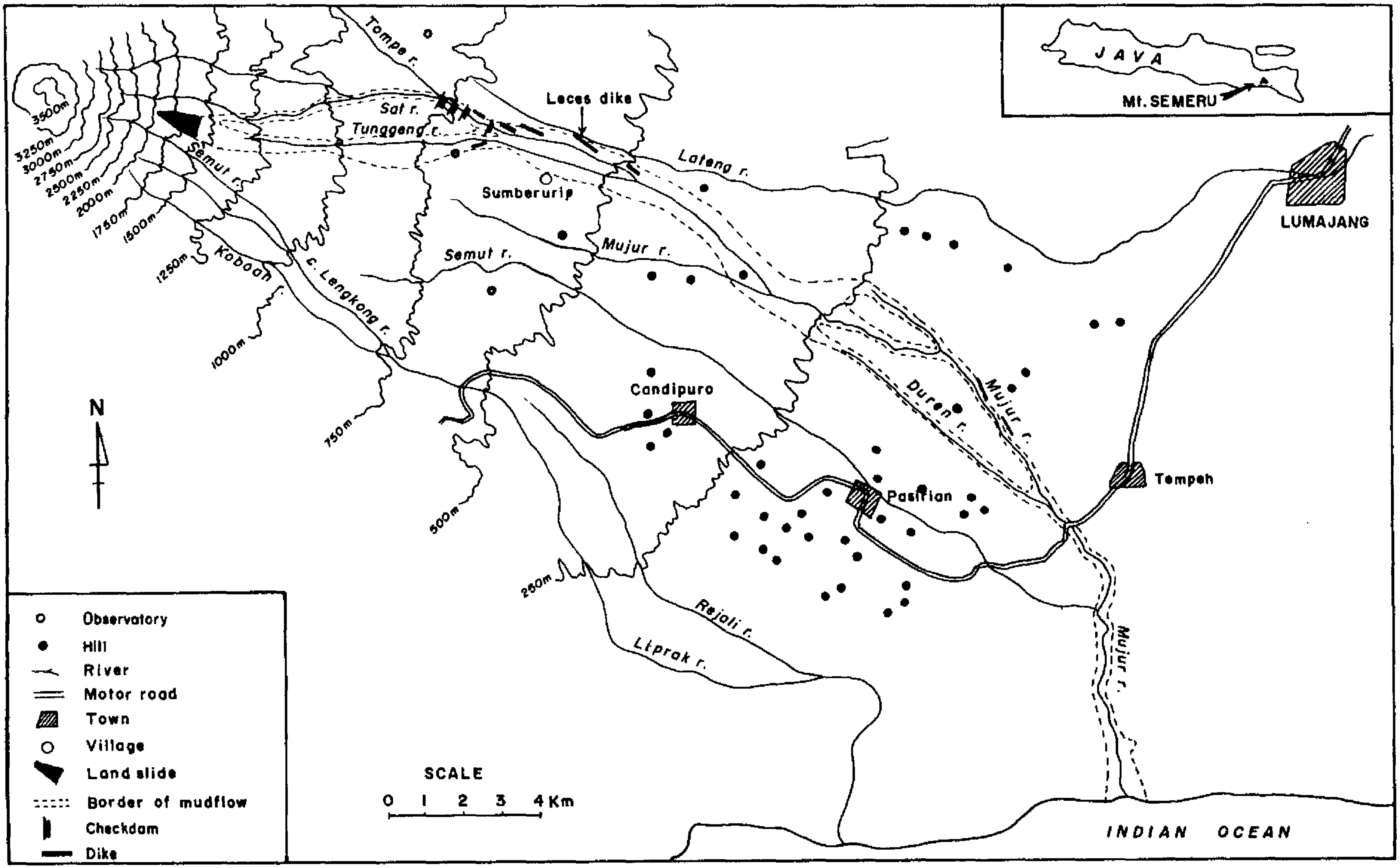

FIGURE 8.7 Mt. Semeru: areas affected by the 1981 mudflow.

FIGURE 8.8 Example of a tong-tong, a device used for lahar warning in Indonesia. *Photo: M. Watanabe.*

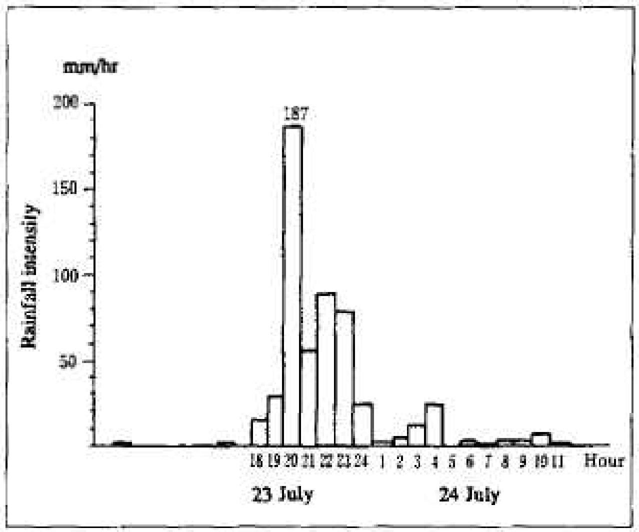

FIGURE 8.9 Hyetograph (rainfall intensity chart) at Nagayo township in Nagasaki, Japan, during 23-24 July 1982.

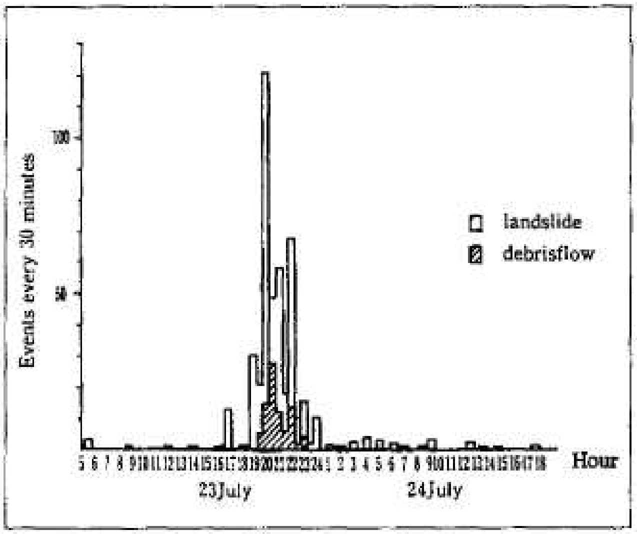

FIGURE 8.10 Number of hazardous events per 30 minutes in Nagasaki during 23-24 July 1982 (Mizuyama and Watanabe, 1982).

time the scene of a major natural disaster. Along with a death toll of 299 people, 1,583 houses were totally or partially destroyed. Mass movements of material from the debris flows and slope failures accounted for 90 per cent of the casualties.

While such a disaster can *prima facie* be attributed to the intense rainfall, the real cause of the disaster was inadequate and haphazard land-use regulations, and reckless town development practices. With an increase in population, the built-up area had been extended from a narrow alluvial bed to mountain slopes without any preventive measures having been taken against potential mass wasting phenomena (i.e., the dislodging and transport downslope of soil and rock material) caused by heavy rainfall.

The lessons learned during a similar disaster thirty years earlier had been forgotten. Disaster prevention measures had not been updated in line with the urbanization of the mountain regions, and there were practically no precautionary provisions for the new housing developments in these regions. The possibility of debris flows was not taken into account during the building of the existing structures. Denuded hillsides, undercut slopes and high embankments without any reinforcement lowered the resistance of the landscape to torrential rainfall (*Fig. 8.11*). By contrast, some slopes with sufficient forest cover suffered no damage.

The congested townships which had developed over small alluvial cones had excessively narrowed river channels. The poor discharge capacity of the channels resulted in flooding and damming by boulders, driftwood and miscellaneous debris.

The Japanese Meteorological Agency had issued warnings of torrential rainfall and associated floods at 1650 hours; i.e., three hours before the height of the disaster. However, since no disaster had resulted following four such previous warnings in that year, this warning was largely ignored.

According to a survey conducted afterwards, only 34 per cent of the people were aware of the warning issued one or two hours before the disaster struck, and 90 per cent of those who received the warning admitted that they did nothing in response. They simply discounted the likelihood of a disaster actually happening, since heavy rainfall was a frequent phenomenon.

It was observed that the mountain slopes were waterlogged from preceding rainfall and that the soil had become unstable. The occurrence of debris flows coincided with the peak intensity of rainfall (see *Figs. 8.9* and *8.10*), which lasted from 1700 hours to 2200 hours, a period when most people were at home.

Flood water entered the lowlands, preventing disaster workers from undertaking any emergency operation beyond issuing an evacuation order at 2150 hours. A power breakdown and the subsequent interruption of the

FIGURE 8.11 Remarkable contrast between clear-cut slopes and slopes with forest cover in terms of slope stability. Location: Nagasaki, Japan. *Photo: M. Watanabe.*

telephone service around 2200 hours made people uneasy. The municipal government was no longer in a position to provide assistance. The evacuation order had no great effect, because there was no longer any means by which it could be disseminated. Even if the order could have been announced using loudspeakers, it might well not have been heard over the roar of the flood water and the noise of the rain beating on roofs and vegetation in the darkness. In fact, the evacuation order had been issued just after the height of the disaster.

While 30 per cent of the people realized that their houses were situated within the danger area, only 10 per cent of that number actually took part in the evacuation. By the end of the emergency phase, 31 per cent of the population had not been evacuated. Thirty per cent of the evacuees took shelter hastily only after the disaster had struck their neighbourhoods. The majority of the evacuees (69 per cent) became aware of the danger on their way to the shelter as rainfall intensified. A housewife called the fire brigade to say that she was faced with imminent danger of a landslide behind her house. She realized that it was high time to evacuate only when a fireman told her to do so. Another housewife threatened she would burn herself if no one came to rescue her.

These reports suggest that people did not evacuate in accordance with proper instructions or procedures prepared beforehand, but simply panicked and frantically sought safety. All these incidents clearly reveal the importance of non-structural emergency preparedness in matters such as public education, information dissemination, hazard delineation, evacuation drills and the professional skills of those responsible for disaster management.

It is easy to say that a community leader should play an essential role in evacuation. In real cases of disaster emergency situations, especially at night, one cannot usually count on others. The difference between life and death in the midst of confusion and panic is the individual's preparedness, judgement and self-reliance.

8.1.6. Surat Thani and Nakhon Si Thammarat Provinces, Thailand (1988)

TABLE 8 1

Daily rainfall during the period of the 1988 debris flows

Daily rainfall in mm	NOVEMBER 1988						
	18	19	20	21	22	23	24
Surat Thani	0.4	7.4	6.1	164.0	283.3	30.7	1.8
Nakhon Si Thammarat		26.4	137.2	447.8	286.9	150.7	2.4

Between 19 November and 23 November 1988, exceptionally heavy rainfall caused widespread mass wasting and flooding in fourteen provinces in southern Thailand. According to the local press (*Bangkok Post*, 3 February 1989), 371 people lost their lives, 16,851 houses were completely destroyed or damaged, and some 3,200 km^2 of agricultural land were affected by the floods.

The damage was most pronounced in the Khao Luang mountains and in the surrounding foothills and flood plains located in the Provinces of Surat Thani and Nakhon Si Thammarat (*Fig. 8.12*). The mass movements included soil slips on steep slopes and debris flows in the stream channels which led to disastrous flooding of the lowlands, creating havoc in communities located on alluvial fans and on the flood plains of streams (*Fig. 8.13*).

Heavy objects, such as large boulders and trees, were deposited and sand was widely dispersed when the sediment-laden streams from the hills met the alluvial fan, where the gradient decreases sharply. Villages located on the alluvial fan and within one or two kilometres of the foot of the mountain and adjacent to the streams, became buried under one to two metres of sand in addition to being inundated by flood water. Debris, consisting primarily of logs, clogged culverts and short-span bridges (*Fig. 8.14*). This caused the river to form new channels leading to the erosion of bridge abutments and approach embankments. The sand-laden flood water also caused the silting-up of wells, the main source of drinking water in those areas.

Debris transported by the streams also caused blockages at narrow locations in side valleys, damming up water. When these dams broke up, the water discharging into the main channel produced surges which were particularly erosive and scoured the banks and the river bed.

There are three main factors believed to be responsible for the widespread mass movements· intense rainfall, deforestation, and geological conditions.

(a) *Rainfall:* Southern Thailand is affected by both the north-east and the south-west monsoons, and the disaster-stricken areas receive a mean annual precipitation exceeding 2,000 mm. From 19 to 23 November 1988, a low depression ridge caused an extremely heavy storm. No rainfall data from the districts which were the worst affected are available. The nearest records are