The complex of city protection (*Fig. 8.49*) includes:

- In the Malaya Almatinka valley:
  - The *Mynzhilki dam*, constructed at 3,000 m altitude, designed to stop mudflows in case of breaches in Tuyuksa glacier lakes. The reservoir created by the dam has a capacity of 0.22 million m^3.
  - The *Medeo dam*, measuring 150 m high, 800 m wide at the base, and 530 m long at the crest, with a capacity of 12.6 million m^3 (see *Fig. 8.49* (a)).
  - The *Damba steel-frame* cell dam and sand-check dyke built at the point where the river flows out of the mountains.
- In the Bolshaya Almatinka valley:
  - The *Great Almaty lake dam* (second stage) at 2,500 m altitude, 10 m high and capable of stopping mudflows of 0.2 million m^3 total volume.
  - A *concrete wall* for mudflow control at the confluence with the Kumbelsu River, for the protection of Hydropower Plant No.1 and related infrastructures and houses in the area.
  - A *reinforced concrete cell* dam 40 m high, 200 m wide at the base and 402 m long at the crest, with a capacity of 100,000 m^3 (see *Fig.* 8.49 (b)).
- *River banks* within the city limits were built up with stabilizing reinforced concrete and sand-check dykes (see *Fig. 8.49* (c) (i), (ii), (iii)).
- *Preventive discharge of water* from glacial lakes, including improvement of forests on the slopes.
- *Construction of roads* leading to structures and buildings in high-risk areas, as well as establishment of an observation and communications network.
- Given that the city of Almaty has 1.35 million inhabitants and is also situated in an area of high seismicity (intensity IX), it was decided that:

(i) A *hazard and risk analysis* should be carried out for the city's structures to enable the preparation of land-use zoning maps.

(ii) All *social and engineering structures* and buildings are to be screened and certified as to hazard-resistance.

(iii) The inspected *structures* should be categorized into three major groups:

(a) *Group one*:	Structures which are sufficiently stable to resist hazards.
(b) *Group two*:	Structures which need retrofitting for strengthening to resist hazards of expected magnitude.
(c) *Group three*:	Structures which cannot be strengthened within economically reasonable limits, and should therefore be removed from the hazardous area.

(The results of the structural screening are shown in the table included in Figure 8.49)

8.4.2. Stava, Italy (1985)

Stava, located in the Fiemme Valley in the Dolomite Mountains of Italy, was a picturesque hamlet and many tourists had been attracted to this tranquil alpine resort. However, in the afternoon of 19 July 1985, this tranquillity was destroyed when Stava was overwhelmed by a giant wave of water and mud resulting from the failure of two 20-year-old dams (*Fig. 8.50*) owned by a mineral company (Alexander, 1986).

The dam site was at a height of 1,200 m and enclosed two basins for washing fluorite ore. Each of the dams was 100 m long, 100 m wide at the base, 50 m wide at the crest and 70 m high. The total volume of the dams was 500,000 m^3 The height of the dams had been increased by earthfilling, using the tips remaining after the processing of fluorite ore.

> "*I was going up towards Stava when suddenly a white wall appeared in the distance . .* ", the Deputy Mayor of Tereso told a reporter.

Two hundred and fifty thousand cubic metres of water, stored in two basins above the valley, had suddenly been released by the collapse of the dams. The water, which carried an equivalent amount of mud, created a wave 30 m high which swept down the valley. After its passage, Stava and all its inhabitants had ceased to exist (*Fig 8.51*).

According to a few eyewitnesses, a spring emerged in the pasture adjacent to the failed dams in the early spring of 1985, when the snow started melting. The dam face had been well maintained up until the dam failure. No information is available, however, of the engineering design of the original dams or the subsequent modifications. The actual failure of the dams was apparently not observed by anyone, so that the exact mechanism of failure may never be known. However, the huge wall-like front wave and the loud noise suggest a sudden failure. The final count of victims included 232 bodies recovered, of which 189 could be identified, and 38 people still missing.

8.5. Concluding remarks

Nineteen (19) cases of mudflow disasters have been reviewed in the present chapter. Each was the result of one or more of the natural and man-made causes described in chapter 2. All the cases presented point to the fact that a disaster can be avoided in many instances, if the hazard is properly identified and the necessary action in response to hazard and risk assessments is taken promptly. Such assessments should, therefore, be the first step in disaster prevention and alleviation in the light of all relevant factors. The second step should consist of preparing scenarios and plans in response to the information acquired as a result of these assessments.

Past experience shows that there has often been some deficiency in the response made to information warning

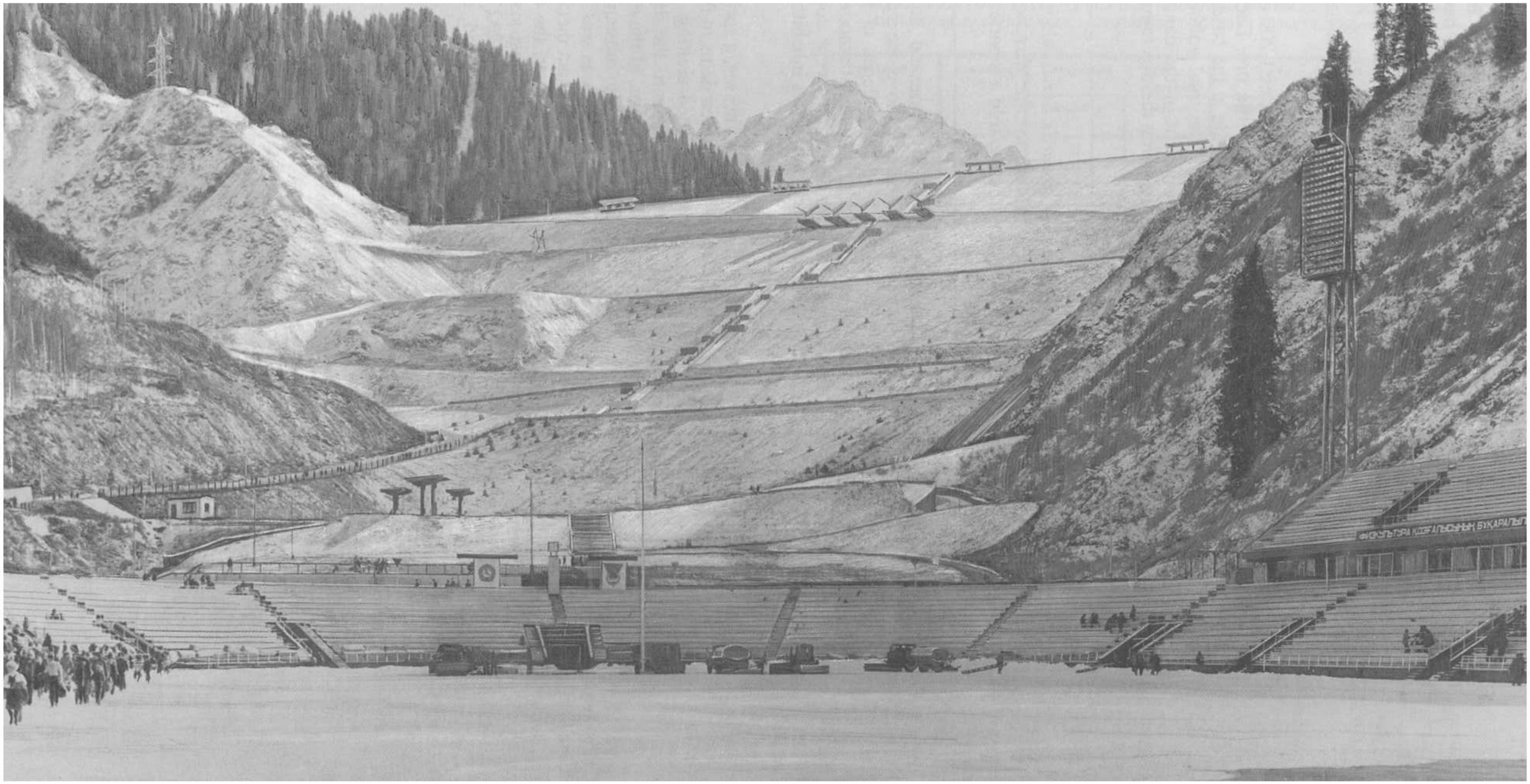

FIGURE 8.49 (*a*) Medeo dam viewed from downstream (Malaya Almatinka River).

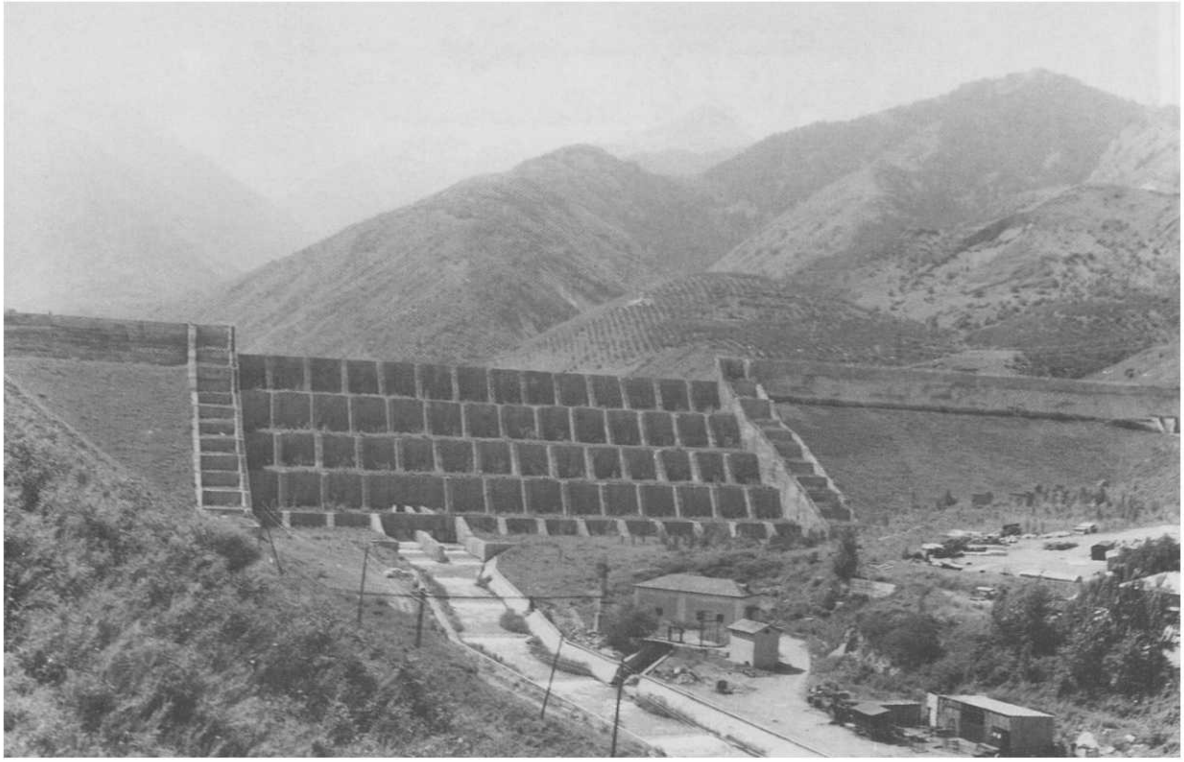

FIGURE 8.49 (*b*) Mudflow protection barrage (steel-cell structure)—Bolshaya Almatinka River.

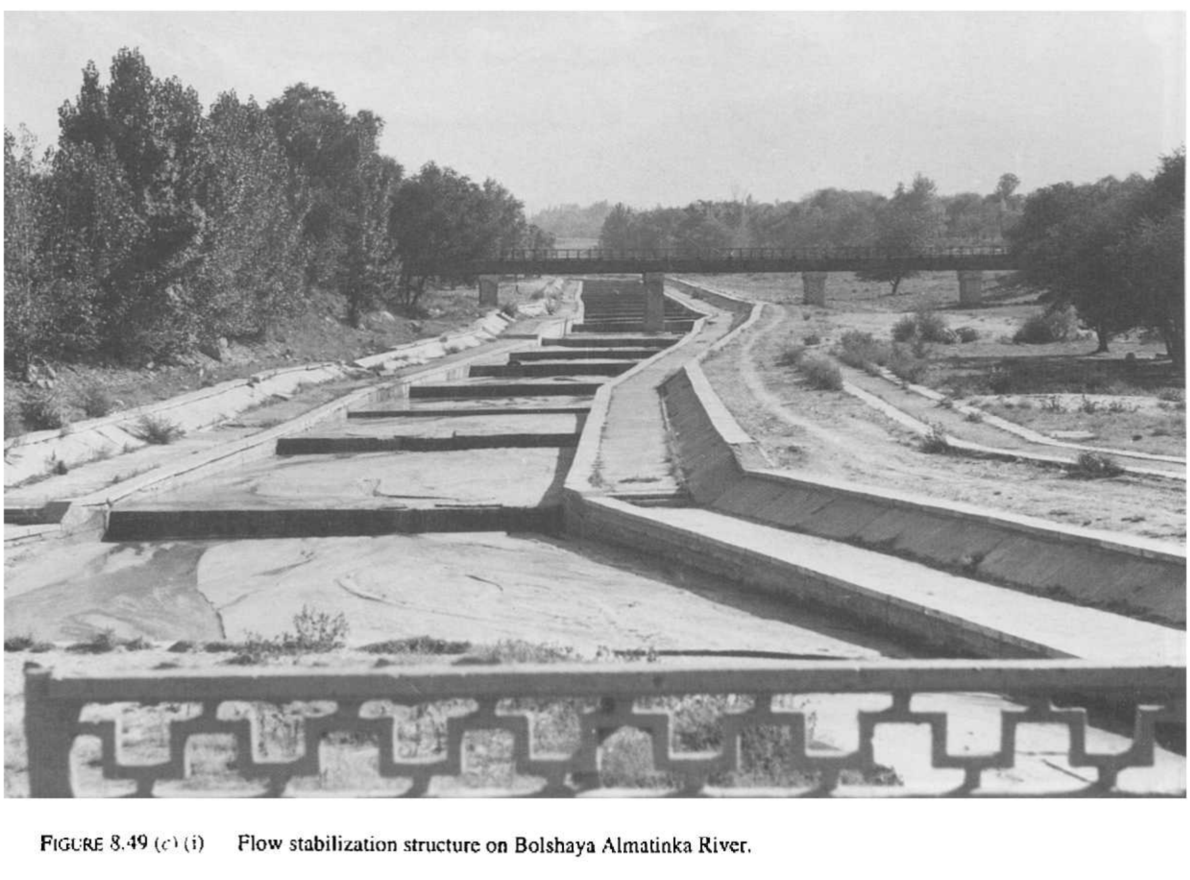

FIGURE 8.49 (*c*) (i) Flow stabilization structure on Bolshaya Almatinka River.

FIGURE 8.49 (*c*) (ii) Mudflow protection wall on the Bolshaya Almatinka River constructed after the mudflow disaster of 1977.

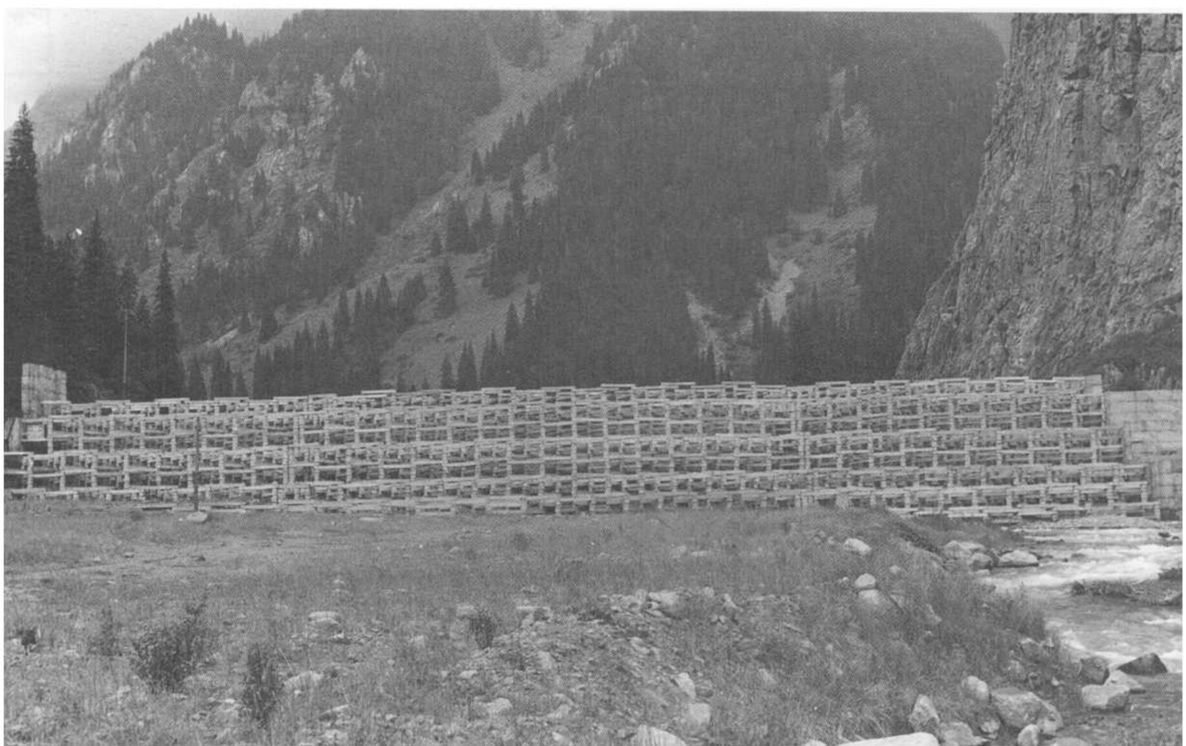

FIGURE 8.49 (*c*) (iii) Steel-cell barrage on Issyk River near Almaty City.
Location: Almaty, Kazakstan. *Photo: State Committee for Emergencies, Kazakstan.*

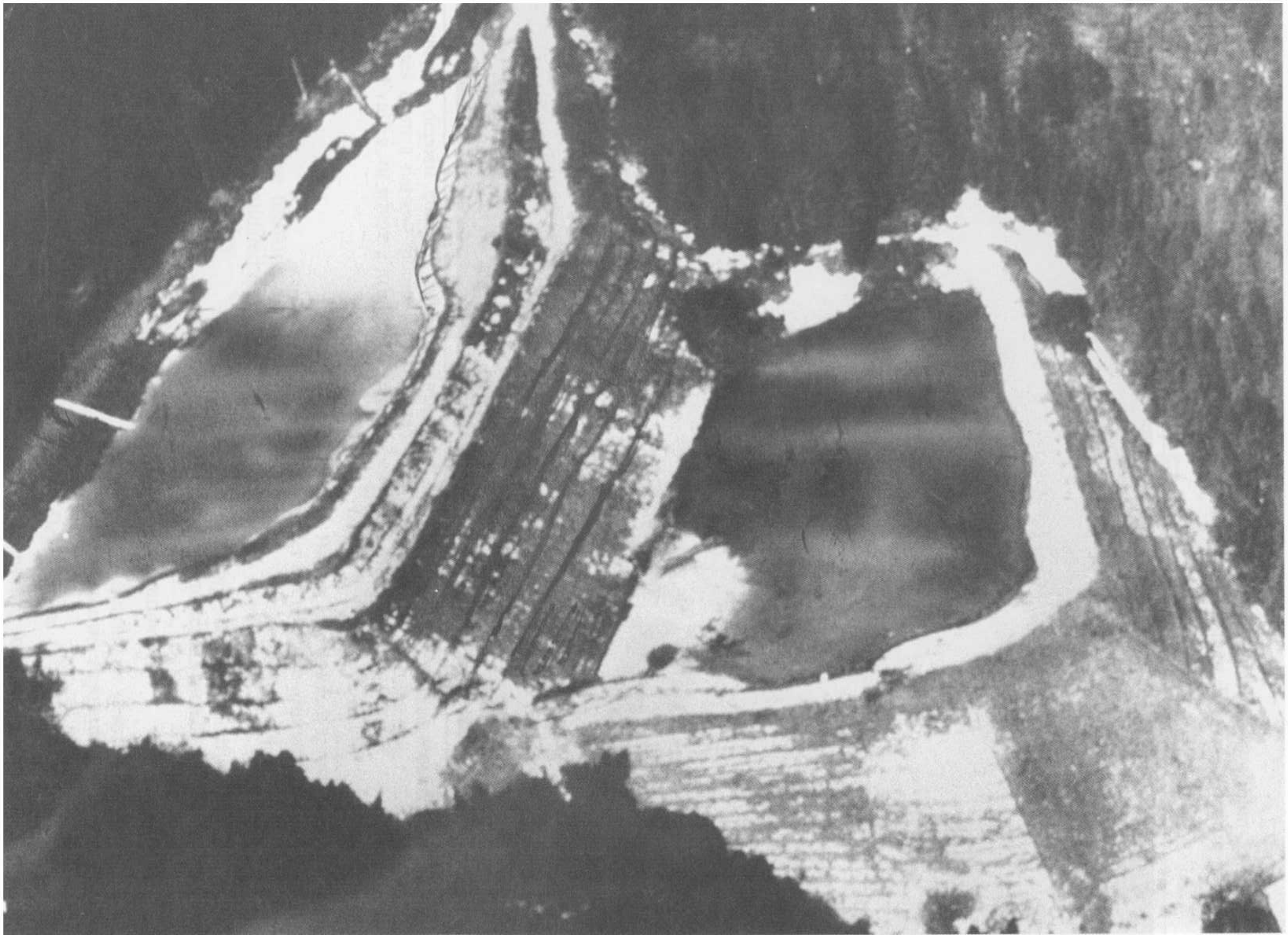

FIGURE 8.50 Two 20-year-old dams which collapsed and caused the destruction of the hamlet of Stava in the Fiemme Valley, Italy, in 1985.
Photo Rizzoli Corriere della Sera, Milano

of potential or imminent disasters. Responses to such warnings have varied from place to place, depending on such factors as available funds, the state of local technology and construction materials. As far as technology is concerned, it is clear that although much remains to be studied, the requisite basic technologies for responding to hazards have been well developed and established.

After the risks of mudflows threatening a particular locality have been properly assessed, realistic scenarios envisaged, and detailed prevention, preparedness, and relief plans have been prepared in consultation with all concerned, the necessary policy decisions must be taken to implement the plans and the required measures. Provided that these steps have been taken, much will have been achieved towards containing the adverse effects of natural disasters. It is appropriate here to quote:

> *Today's act of God is yesterday's criminal act of negligence.*

FIGURE 8.51 Stava after the 1985 mudflow. *Photo: ANSA*