APPROACHES TO REDUCING THE HAZARD OF AN OUTBURST FLOOD OF IMJA GLACIER LAKE, KHUMBU HIMAL

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Glacial lakes are a common feature of the Himalaya in general and the Khumbu Himal region of eastern Nepal in particular (Ives 1986). Most of these lakes tend to be stable and pose little threat. However, some glacial lakes are naturally unstable because of the conditions that contain them. Many catastrophic floods have occurred in the Himalaya when a dam of moraine and/or ice failed suddenly and released massive amounts of water that had been stored in a glacial lake. In recent years, several glacial lake outburst floods in and near the Khumbu region have demonstrated the hazard (Yamada and Sharma 1993). An outburst from the Nare Glacier above Mingbo and Pangpoche in 1977 destroyed several houses along the Dudh Kosi River. In August 1985, the moraine dam of Dig Tsho in Langmoche Valley failed catastrophically, and the resulting flood destroyed the almost-completed hydroelectric plant near Thamo and disrupted trade and tourism throughout the region. About three million cubic metres of debris were transported dozens of kilometres downstream. In July 1991, the flood from Chubung lake in the Ripimo Shar glacier scoured the Rowaling valley and damaged structures near the river in Beding. Erosion was limited to tens of thousands of cubic metres of material in this small outburst. Field observations of changes in affected river channels caused by the latter two events were made in 1982, 1992, and 1994 in the Langmoche case and in 1983 and 1992 in the Rowaling case.

A lake continues to grow on the surface of the Imja Glacier east of Dingboche in the Khumbu region (Watanabe et al.1994). This glacial lake may be a serious natural hazard to villages immediately downstream and the

Dudh Kosi valley in general because of the possibility of a massive flood if its ice-cored moraine dam were to fail. Early indications suggest that a major hazard already exists but that failure of the moraine dam is not imminent. The lake is much larger than Dig Tsho and is located only a few kilometres above the villages of Dingboche, Pangpoche, and Phunkithangka, which are close to the river channel. Further downstream, villages such as Jorsale and Phakdingma and isolated homes and fields on river terraces could be severely damaged.

At the request of Khumbu residents, site investigations were made in 1994 to evaluate the feasibility of reducing the hazard of an outburst flood. The application of a siphoning technique (Grabs and Hanisch 1993) seems to be appropriate to the conditions. A siphon system is currently being tested at Tsho Rolpa in the Rowaling valley (Damen, personal communication). This test and its eventual expansion is an important development in engineering for reduction of the hazard of glacial lake outburst floods. Although the siphoning approach appears to be relatively effective, practical, inexpensive, and safe, there remains a substantial risk of seismic events, ice calving, mass failure of the lateral moraines, rapid incision of the outlet channel, and piping through the terminal moraine until the lake level is lowered. In the case of Imja Lake, there may be opportunities to harvest sections of the winter ice cover and move them over the moraine and to carefully excavate the long outlet channel in a sequential manner. Flood warning systems are a valuable intermediate step in reducing hazards to people (Kattelmann 1994). A warning system for the Imja and Dudh Kosi valleys, using observers and reliable radio communications is necessary until the risk of an outburst is reduced. Imja Glacier Lake presents a rare opportunity to actively reduce a natural hazard instead of just respond to the eventual damage.

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