Floods in mountain watershed: A case of Madi River, Central Nepal

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ABSTRACT:
This paper highlights the type, magnitude, recurrence interval of floods in Madi River and the damages associated with it. Historical information on floods in the watershed before 1978 was collected through group discussions in different parts of the watershed. Attempt has also been made to analyze the data compiled by the Department of Hydrology and Meteorology, HMG/Nepal at Sisaghat located in the middle part of the watershed after 1978. Analysis of the data so far available shows that high magnitude destructive floods in the mountain areas are triggered by landslide and debris flow. They are associated with high intensity precipitation. Many of the destructive floods occurred in the 1950's and confined either in areas with narrow river channel or upstream of the confluence point of two major tributaries. They were associated with blocking, damming and backwater effects. The downstream areas are highly affected by the floods triggered due to landslide and debris flow in the remote upstream areas.

1. INTRODUCTION

Nepal Himalayas are naturally very dynamic because of its rugged topography, highly concentrated monsoon precipitation and very active tectonics. The topography ranges from less than 70 to 8848 m a.s.l. within a north-south distance of less than 160 km Tarai, which is northern extension of Indo-Gangetic plain, comprises only 14 percent of the total area of the country. Rest of the area is mountainous. Nearly 80% of the area of the country comprises of steep to very steep terrain with four different mountain systems – the Siwalik, the Middle Mountain, the High Mountain and the High Himal. Up to 80 percent of the total annual precipitation occurs in four summer months (June-September) and 37 percent of the average annual rainfall occurs within 24 hours. Precipitation event with 540 mm was recorded in Tistung in 1993 and many events with more than 400 mm within 24 hours have been recorded in the country (Chalise and Khanal 2002). Earthquakes of different magnitudes occur frequently in the country. As a result, different types of geohydrological hazards such as flood, landslide, debris flow, outburst of glacial lake and landslide dam are common in the country. The increasing human activities in such a dynamic natural environment as a result of rapid increase in population, increasing number of infrastructures without due consideration on the dynamic of the environment have aggravated natural processes turning hazard events into disasters. 325 people die every year due to flood and landslide (Department of Narcotics Control and Disaster Management, HMG/Nepal). The number of people killed from such disasters in the country is 35 persons per million living population whereas it is only 2 persons in Bhutan and Myanmar, 3 in China, 6 in India and 7 in Pakistan. Nearly 3 percent of the total household income is lost every year due to natural hazards in the country (ICIMOD, 2002). At national level, nearly 10 percent of the total Gross Domestic Product (GDP) is lost due to damages of infrastructures and other properties from flood and landslide. In this context, proper understanding of the nature of events and the causes of loss of life and properties is necessary for the development of appropriate strategies in order to reduce the increasing loss in the country. This paper aims to highlight the type of floods and the losses that were occurred in the Madi watershed since 1950s.

2. METHODS AND MATERIALS

2.1 STUDY AREA

Madi Khola, with a catchment's area of 1124 sq km has been selected for the study (Fig.1). It is one of the major tributaries of Gandaki river. The altitude

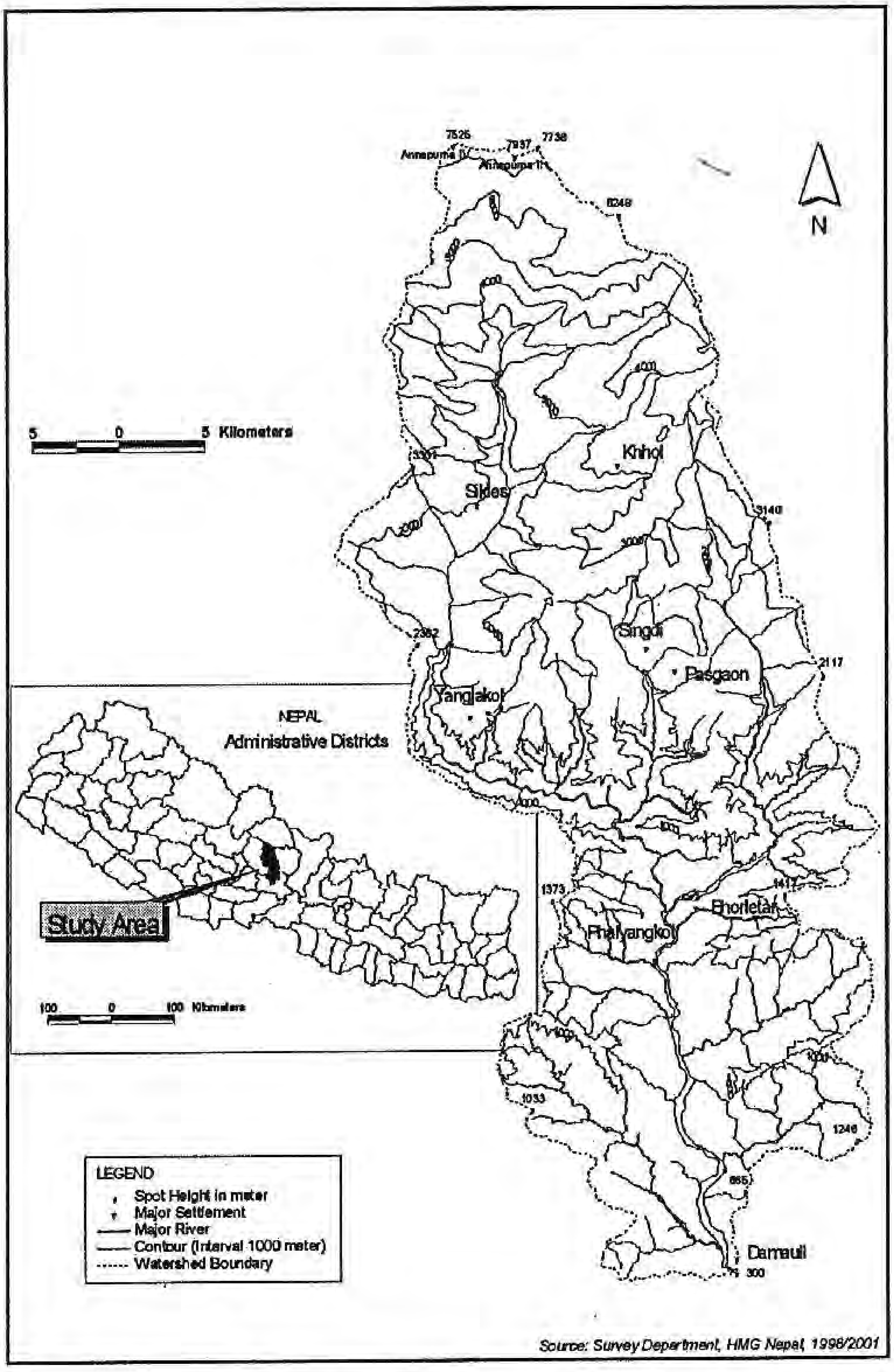

Figure 1. Location of Study Area

of the Madi watershed ranges from 300 m in the south to 7937 m in the north with an aerial north-south distance of 68 km. The climatic condition ranges from subtropical in the south to alpine and artic in the north. Nearly 20 percent of the total basin area lies above 3,000 m altitude. About 92 percent of the total area comprises of steep to very steep slopes. In terms of land use and land cover, 25 percent land is under cultivation, 5 percent under snow and ice cover, 2 percent under sand and water and the remaining comprises of forest, shrub, grazing etc. The population density in the watershed is 119 persons/sq km. Mean annual precipitation in the watershed ranges from 1,795 mm at Damauli in the south to 3,743 mm at Sikles in the northwest. Both the spatial and temporal concentrations of precipitation are noticed. The average number of rainy days ranges from 103 days/year at Damauli and Kunchha to 187 days/year at Sikles. Nearly 70-80 percent of the total precipitation occurs in four summer months (June- September). Winter months are drier.

Cloudburst is a common phenomenon, which causes landslides and floods. Madi river has 9 major tributaries with basin area more than 11 sq. km. These include Rudi, Midim, Paste, Birdi, Khalte, Pisti, Risti, Sange and Kalesti.

2.2 DATA

Both primary and secondary sources of information have been used. Historical information on floods before 1978 were collected through group discussions in different parts of the watershed.

Table 1. Mean monthly and instantaneous discharge at Sisaghat in Madi river (discharge in cumecs and gauge height in meters)

Year	Mean discharge													Maximum instantaneous		Minimum instantaneous	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Discharge	Gauge height	Discharge	Gauge height
1978	18.9	15.8	16.4	20.3	42.2	108	282	270	168	84.3	45	31.9	92.6	592	3.04	13.6	0.37
1979	24.5	22.3	19.5	23.6	35.9	60.8	261	392	192	65.6	30.2	19.4	96.4	2570	7.23	16.6	0.56
1980	13.6	12.1	13	13.6	17	52	318	367	235	47.2	22.9	14	94.4	945	4	4.4	0.4
1981	10.1	8.05	8.19	14.9	23.9	61.8	303	279	152	57.2	30.9	19.7	81.4	866	3.8	4.4	0.4
1982	16.4	15.2	18.3	21	25.6	64.6	175	na	na	62.8	44.1	35.1	na	866	3.8	12.4	0.51
1983	29.9	27	27.8	27	41.3	56.6	139	201	217	106	45.1	25.5	79	1150	4.5	20.8	0.72
1984	17.1	12	12.4	14.2	51.4	124	354	205	167	77.3	48.6	33.1	93.5	1380	5	8.92	0.56
1985	24.9	22.6	22.2	26.4	41.2	77.6	225	133	137	85.1	38.1	24.3	71.9	500	2.75	15.7	0.4
1986	16.7	13.3	14.4	19.2	18.8	79.4	176	175	189	99.7	39.9	20.7	72.2	470	2.81	8.99	0.17
1987	15.9	13.8	14.5	16	21	48.7	189	189	124	58.9	36.6	26.5	63.2	568	3.1	12	0.24
1988	20.4	18.1	18.2	19.4	27.5	75.3	178	216	161	69.3	35.7	26	72.4	467	2.8	15.4	0.31
1989	22.9	18.7	18.8	20.6	40.1	98.9	170	210	162	76.9	36.3	24.6	75.4	406	2.6	13.6	0.5
1990	19	16.7	17.5	24.2	37.2	103	183	197	188	na	na	na	na	548	3.04		
1991	na	na	na	na	na	136	190	216	169	79.1	38	26.3	na	432	2.9		
1992	21	18.8	17.8	17	24.1	55.3	128	196	133	84.2	33.9	20.6	62.7	329	2.55	14.1	0.5
1993	15.7	13.9	9.77	9.92	20.3	66	147	217	145	82.6	38.4	22.5	66.2	420	2.86	6.81	0.31
1994	22	20.2	22.3	22.8	29.1	80	131	148	107	29.4	10.7	na	na	329	2.55	6.21	0.29
Average	19.3	16.8	16.9	19.4	31.0	79.3	208.8	225.7	165.4	72.9	35.9	24.7	78.6				

Source: DHM, 1998; 93-96

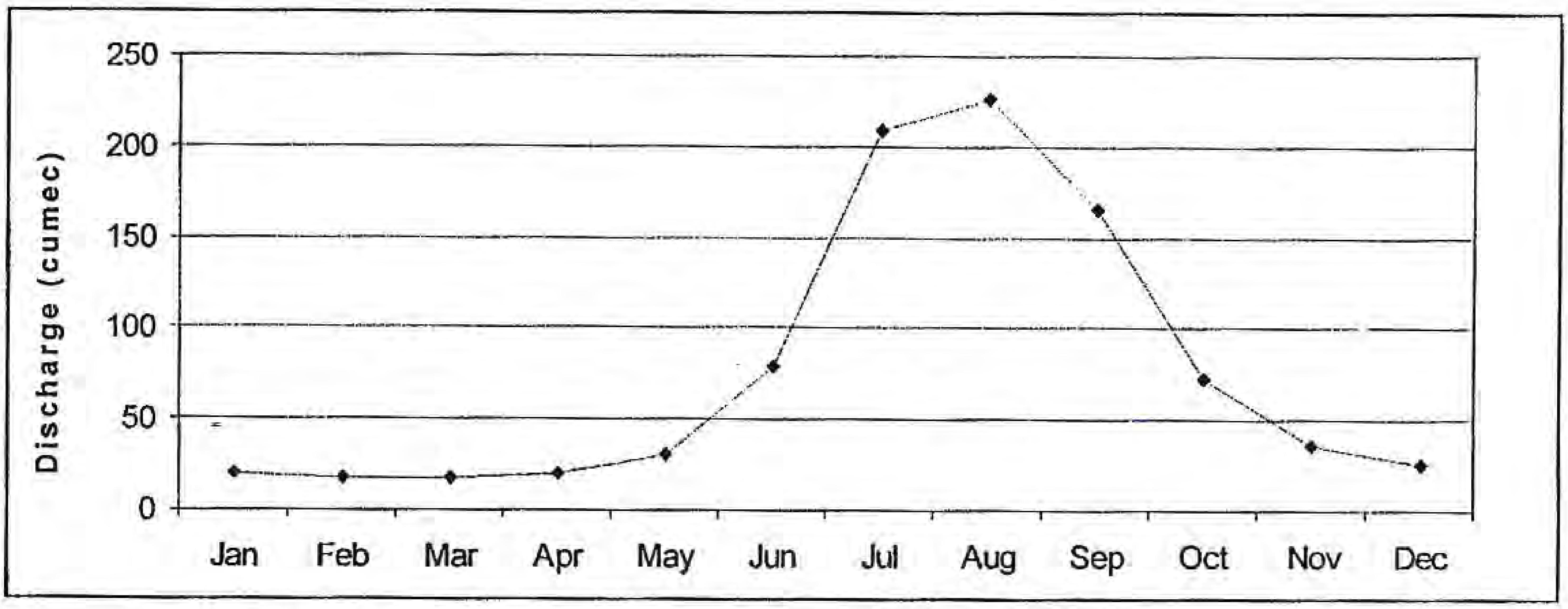

Figure 2. Mean Monthly Discharge of Madi river at Sisaghat (1978-1994).

Fieldwork was carried out extensively in 1999. The discharge data collected by the Department of Hydrology and Meteorology, HMG/Nepal at Sisaghat located in the middle part of the watershed after 1978 has been analysed.

3. RESULTS

Annual discharge in Madi watershed recorded at Sisaghat ranges from 62.7 m^3s^{-1} to 96.4 m^3s^{-1} with an average of 78.7 m^3s^{-1} (Table 1). Monthly discharge peaks in August (Fig. 2). Maximum instantaneous discharge ranges from 329 m^3s^{-1} to 2570 m^3s^{-1}. The ratio of maximum instantaneous discharge to minimum is more than seven times for the period between 1978 and 1994. The instantaneous discharge was more than the average plus one standard deviation in 1979 and 1984 (Fig. 3). The reactivation of landslides in 1979 in Danduwa in Midim sub-catchment released a large volume of sediment, which resulted in the flood in Madi river. Extreme flood events reported by the people from different parts of the Madi watershed are summarized in Table 2.

Flood events destroying large area of cultivated land along the river occurred in 1949, 1951 and 1954 in many places. Many landslides were riggered by the precipitation events of 1949, 1951 and 1954 resulting flood in many rivers. Interpretation of aerial photographs taken in 1956/58 shows more than 236 landslide and debris flow scars, mainly located in the middle and upper parts of the watershed (Fig 4). Many of the landslide and debris flow scars initiated by heavy rainfall of 1949, 1951 and 1954 have stabilized. The number of active landslide decreased to 18 in 1972 and 5 in 1979 as recorded from aerial photographs (Khanal 1999b). Madi river was blocked in 1949 and again in 1951 by the logs and debris brought by the river from the middle and upper parts of the watershed at Ghumaune, a few meters upstream of the confluence of Madi with Seti river (Fig. 5). Large area was flooded due to the blocking of Madi river. Khet land located along Madi river and its tributaries like Sange was buried with the debris brought by the river. Madi river was blocked by the flood in Rudi khola in 1951. A few km length of Madi upstream of the confluence point was flooded. It destroyed 12-15 ha of Khet land located along Madi and Rudi river. Landslide initiated in remote upstream area caused flood in Midim river. Khet land along Midim river near Bhujung was destroyed by the flood in Rudi Khola in 1951. A few km

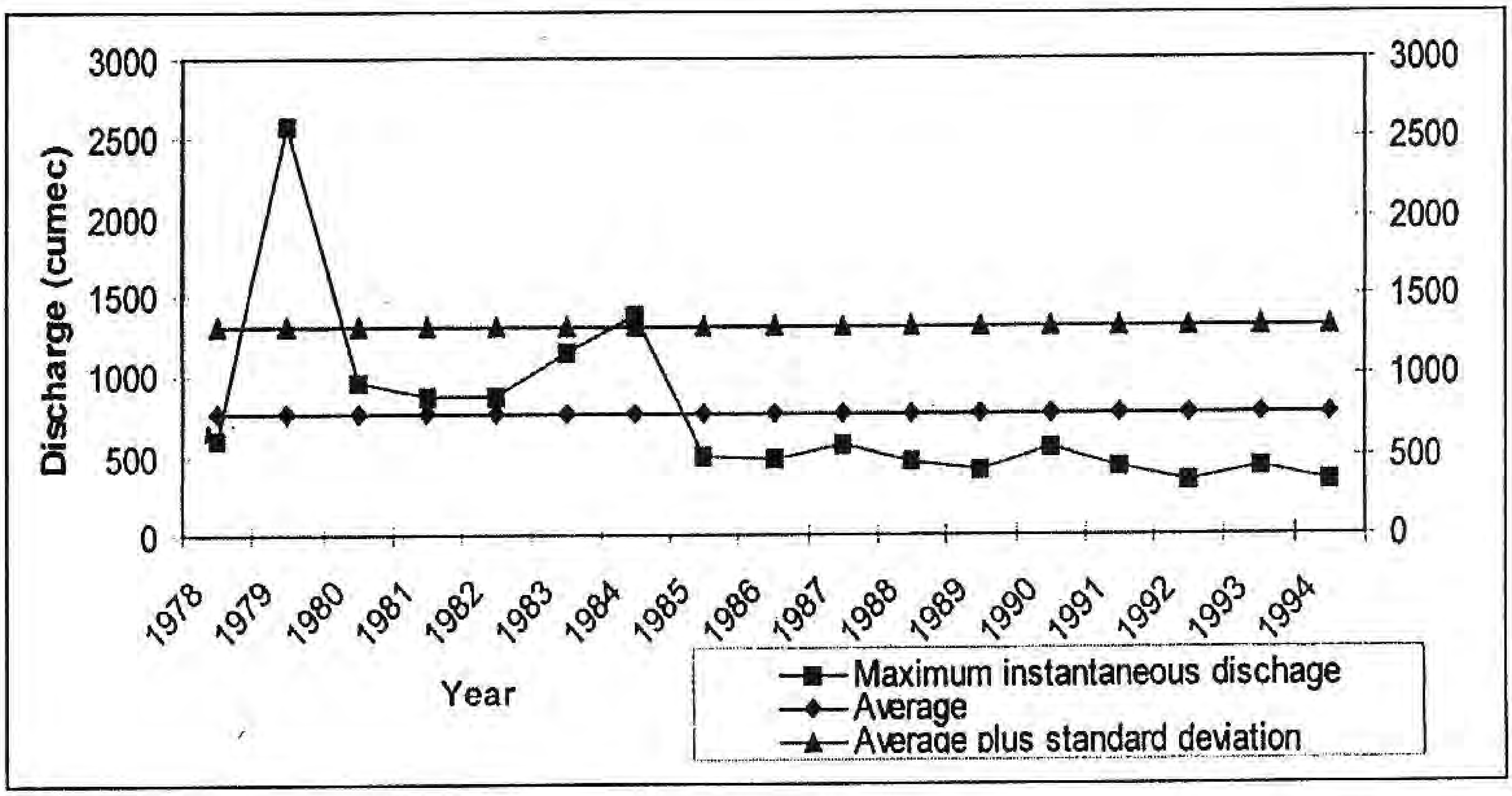

Figure 3. Maximum Instantaneous discharge (1978-1994)

Table 2: Flood and landslide events with losses and damages

Year	Places	Description of the events and damages
1949	Bhujung	Many landslides occurred; huge trees of champ brought by Midim Khola, bridges were swept away, cultivated land along the river destroyed; animals were also swept away.
	Sikles	Many large landslides in the upper part of the watershed, huge flood with large boulders initiated many landslides along the river, almost all khet land along the Madi river were destroyed and still large area destroyed by this flood has to be reclaimed
	Taprang	Flood in Madi river initiated landslide, which eventually damaged many houses and agricultural land
	Damauli	Madi river was blocked at a few meters upstream from the confluence with Seti river and almost all the khet land along Madi and its tributaries were buried by sand and gravel.
1951	Bhujung	Flood in Midim river swept away water mill and bridges. Two persons working in water mill were also swept away.
	Rudi Dobhan	Heavy rain in July caused landslide, debris flow and flood. Rudi khola, the tributary of Madi blocked Madi river and about 12-15 ha of khet land was damaged by the flood. Still large area destroyed by this event has to be reclaimed
	Bhorletar	Madir river was flooded
	Damauli	Madi river was blocked again and destroyed khet land
1954	Rudi Dobhan	Khet land along the Madi river was destroyed
	Bhorletar	Madi river was flooded and khet land along the river was destroyed
	Damauli	Madi river was again flooded
1957	Sikles	Big flood in the Madi river
	Rudi Dobhan	Flood in Handi khola destroyed about 3 ha of khet land
	Bhorletar	Both Midim and Madi river flooded and destroyed agricultural land along its course
1971	Damauli	Madi river was flooded again
1974	Bhujung	Flood in Midim river swept away water mills, 6 pairs of oxen and two persons
1976	Majhathana	A big landslide and debris flow at Paire caused flooding in Madi river
1979	Taprang	Landslide initially started in 1949 reactivated and enlarged, feeding large volume of sediment in Madi river
	Danduwa	Landslide initiated in 1975 reactivated and enlarged. About 5 ha of khet land along Midim khola destroyed by the flood triggered by this landslide

Source: Field Survey, 1999/2000

length of Madi upstream the confluence point was flooded. It destroyed 12-15 ha of khet land located along Madi and Rudi river. Landslide initiated in remote upstream area caused flood in Midim river.

Khet land along Midim river near Bhujung was destroyed. Extreme flood event occurred again in Rudi and Midim river in 1957. Landslide and debris flow in Taprang and Danduwa fed large volume of sediment in both Madi and Midim river causing flood in these rivers. Large area of Khet land along these rivers was destroyed.

4. DISCUSSION AND CONCLUSION

The experience from Madi watershed shows that landslide and debris flow in the mountains on the one hand and blocking of river from logs and debris in narrow channel section and from flood in tributaries at the confluence point trigger floods damaging large area of cultivated land. Though there are few glacial lakes in the upper part of the watershed, no event of glacial lake outburst flood has been reported by the people. It is also reported that the landslide in remote upstream area triggers floods in downstream area. Outburst of landslide dam is also another cause for triggering flood reported from other mountain areas in the country (Khanal 1995 & 1997). It is in this context that watershed condition and channel morphology are also important factors in triggering flood in mountain areas.

Extreme flood events triggered by landslides and debris flow have been reported from different parts of eastern and central Nepal in 1954. The maximum flood level was recorded in Kosi river. Similarly,

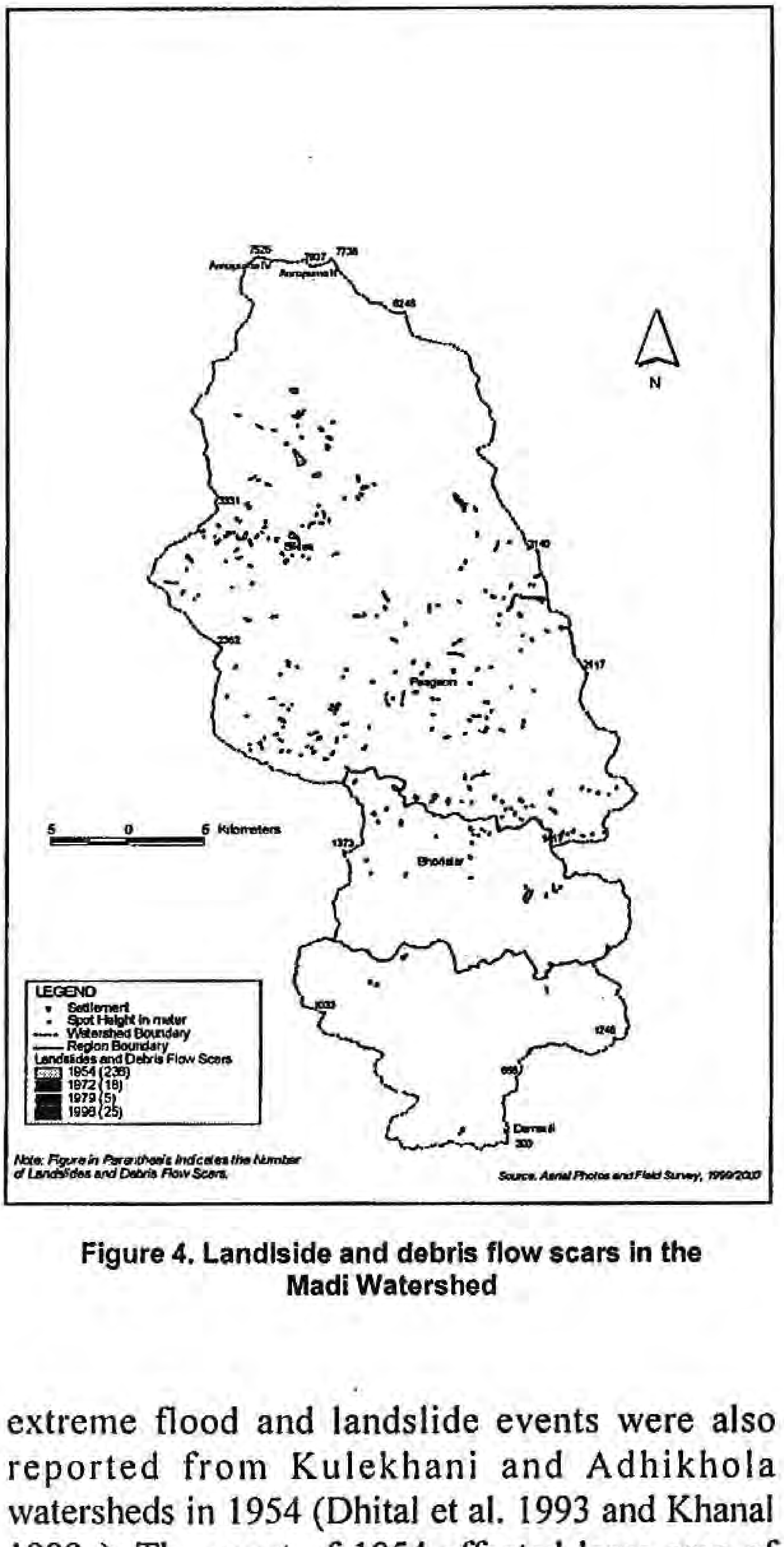

Figure 4. Landlside and debris flow scars in the Madi Watershed

extreme flood and landslide events were also reported from Kulekhani and Adhikhola watersheds in 1954 (Dhital et al. 1993 and Khanal 1999a). The event of 1954 affected large area of the country. The damages from landslide and flood events of 1954 forced large number of people to leave their localities. The eradication of malaria in 1956 in the Tarai, Inner Terai and river valleys has further attracted people to migrate from hillsand mountains ffected from landslides and floods. The development of road network, market towns and other service infrastructures such as schools and hospitals in the valleys after

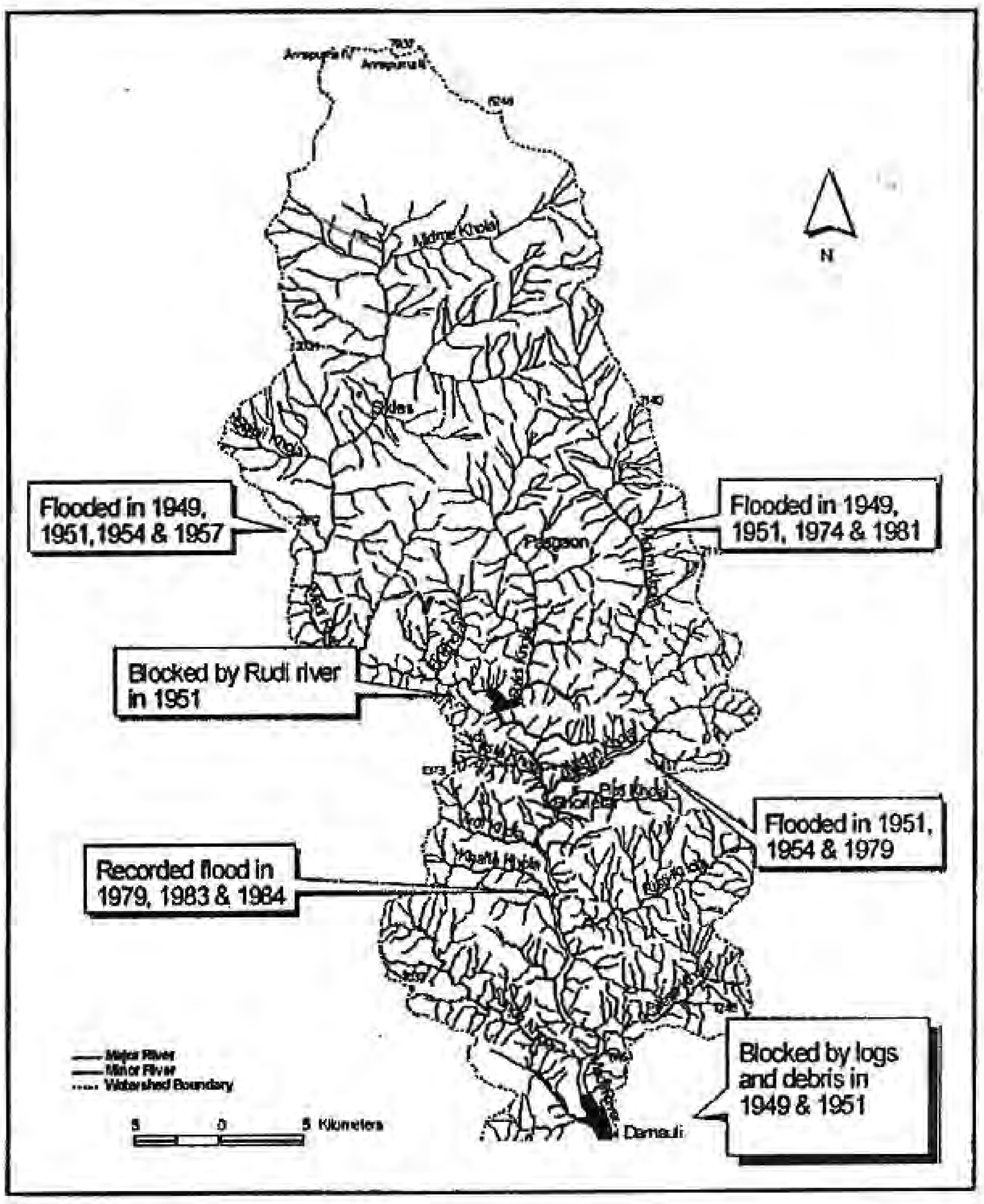

Figure 5. Extreme Flood in the Madi Watershed

1970s caused large-scale migration from ridge to river valleys. The increasing demand for water in recent years as a of the maintenance of rain water harvesting system n the ridge is another factor for large scale migration from ridge in the middle hills to the river result of changing lifestyle and decreasing supply due to drying out of natural springs and weakening valleys. Large-scale migration from the hills and mountains to the river valleys has increased the level of exposure of people and properties in flood prone areas. As a result, the loss from flood has been increasing. It is likely that the loss of life and properties will increase and the livelihood of the people will be affected seriously in the future if efforts to minimize the risk and vulnerability are not made.

Flood forecasting and warning are some of the non-structural measures for reducing the loss of life and properties from floods. Rainfall-runoff model primarily based on precipitation is necessary but not sufficient for flood forecasting and warning in mountainous areas like ours where many other location specific factors are responsible for triggering the event. So, periodic monitoring of watershed condition and channel morphology is also necessary in order to accurately forecast the magnitude of flood and assess the risk and vulnerability of people and properties.

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