Chapter 12
Some Socio-Economically Significant Landslides in Uttarakhand Himalaya: Events, Consequences and Lessons Learnt

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Abstract The Uttarakhand Himalaya is susceptible to landslides due to various causes including its physiographic conditions, adverse geological setting, heavy to very heavy precipitation, intense seismic shaking, rapid glacial melting, inadequate drainage and severe toe erosion, deforestation, unscientific mining, ill-construction and improper land use etc. Several of these landslides have resulted in loss of human lives, livestock, livelihood and damages to buildings, infrastructure, utilities and services. The chapter briefly discusses about some of these socio-economically significant landslides from Uttarakhand Himalaya along with their consequences and lessons learnt. The socio-economically significant landslides have been defined as those landslides that resulted in loss of human lives or heavy economic damages/ losses beyond the coping capacity of the affected community.

Uttarakhand Himalaya is also prone to earthquakes and lies in seismic zone V and IV. The area was affected by two major earthquakes during the years 1991 and 1999 that caused numerous landslides. But the present chapter focuses mainly on the water related landslides that are more frequent and widespread in this area. An attempt has been made to enlist most of the important landslide events in tabular form along with their location, date/month/year of occurrence and impacts. Seventy-eight landslide events have been reported between the year 1800 and 2011. But the chapter briefly discusses a few events to highlight the consequences and lessons learnt from the past landslides in Uttarakhand Himalaya. These landslides include Sher-ka-Danda Landslide (1880) in Nainital, Kaliasaur Landslide (1920 onwards), Alaknanda Tragedy (1970), Malpa landslide (1998), Bheti Paunder Landslide (1998), Phata Landslide (2001), La Jhekla Landslide (2009), and Kapkot Landslide (2010).

Keywords Himalaya • Landslide • Lessons • Risk • Socio-economically significant • Uttarakhand

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12.1 Introduction

Major portion of the Uttarakhand State is mountainous. Human settlements are scattered on hill slopes which experience repeated landslides that are often located in the vicinity of major Himalayan thrusts and faults. This situation is further aggravated by the haphazard landuse practices. The ability to respond quickly to major disasters is also handicapped by the lack of efficient transport network—existing roads are the only means in the absence of proper rail network or airports. Furthermore, most of the population centres in the State are in rural environment where the paucity of both transport and communication facilities severely strain the capacity to respond quickly in the wake of disaster.

All these considerations place the State administration in a state of dilemma. On one hand, it must find the substantial investment for development planning to raise the standard of living of its citizens. On the other hand, there is urgent need for an effective disaster risk reduction plan. These plans should have a focus on landslide problems. An essential element of such a plan should be to identify and assess the distribution of landslides, their magnitude, frequency and impacts on society and environment. The basic approach should be aimed at promoting self reliance in the communities at risk, thus, building up a sustainable resilience of the system to the impact of future hazards.

The chapter provides information about socio-economically significant landslides that must be considered by the State administration while preparing plans for reducing landslide risk from future hazards. Figure 12.1 represents the location of the study area in India and its administrative divisions on the basis of districts in the state.

Table 12.1 gives the location and date/month/year of occurrence of landslides along with their consequences in terms of losses of human lives/livestock and damages to economy and infrastructure.

12.2 Brief Description of Some Socio-Economically Significant Landslide

12.2.1 Sher-Ka-Danda Landslide

On Saturday 18 September 1880, a landslide took place at the north end of the town (Fig. 12.2a, b), following heavy rainfall for 3–4 days and an earth tremor, burying 151 people. A large number of buildings were swept away in a matter of a few minutes and the landslide debris covered the slopes as well as filled a part of the lake. In fact, the flat area at the toe of the slope represents the filled up portion of the lake. Two days preceding the slip there was heavy rain, 20–25 in. fell during the 40 h ending on Saturday morning, and the downpour still lasted and continued for

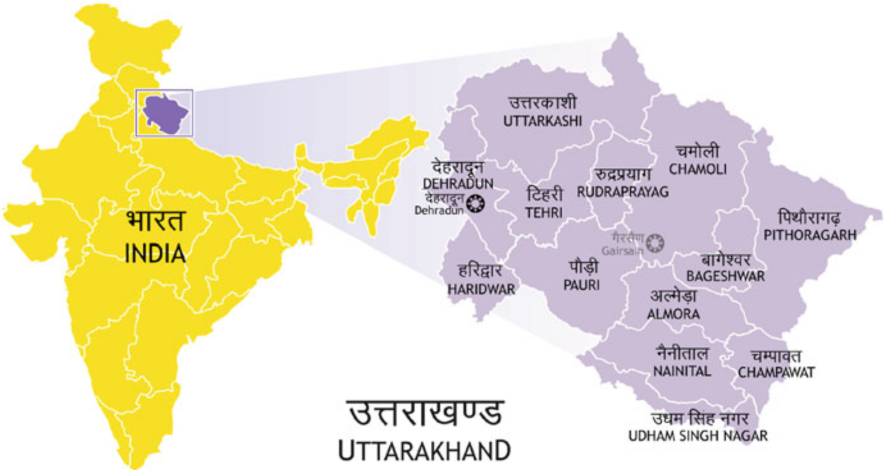

Fig. 12.1 Location Map of Uttarakhand State

hours after the slip. To prevent further disasters, storm water drains were constructed and building bye-laws were made stricter.

The presence of a longitudinal fissure, at the top of the Sher-Ka-Danda ridge, running almost over the full length of this ridge is considered to be a tensional opening due to the slow gliding of the entire slope along deep seated cleavage planes or shear zones dipping towards the lake. The presence of highly puckered fissile and weathered slate, in the slope areas, indicates gradual movement of the slope towards the lake. The debris covered areas and the slope steeper than 30° commonly show the presence of tilted trees. The exploratory studies carried out near the base of the slope reveal the presence of thick fluvio-glacial upper material, lake sediments and landslide debris. It also shows that there is no toe support of bedrock even at a depth of more than 60 m for this slope,

Observations on the movement of the hill slope for a period of about 70 years conducted by the Geological Survey of India have shown that the cover of the hill has been creeping downhill with a gradual diminishing rate of movement reaching an insignificant level.

Later during 1980s when a ropeway was constructed at this location, slope stability has been improved by adding to the shearing resistance of the rock mass at the incipient plane of sliding. This can be accomplished either by (a) grouting the rock mass chiefly to improve the overall shear strength or (b) providing rock bolts/ anchors chiefly to add to the effective normal pressure on the potential plane of sliding. Grouting is expected to improve both c' (effective cohesion) and φ' (effective angle of internal friction) values but inhibit natural drainage. Rock anchoring is expected to improve effective normal stress values particularly in the zone of sliding.

Table 12.1 Data on socio-economically significant landslide in Uttarakhand State, India between the years 2011 and 1800 (Parkash 2011)

Sl. No.	Location	Month/year	Damages
1.	Daur Gaon, Narendranagar block, Tehri distt	11 September 2011	Six members of a family killed and four houses collapsed
2.	Almora distt	21 July 2011	One killed four injured, jeep damaged
3.	Chamoli	21 July 2011	One killed one injured, bus damaged
4.	Tamenglong, Manipur	6 July 2011	Six killed seven injured, NH-53 closed
5.	Chamoli	30 June 2011	Ten killed, Rishikesh-Badrinath closed
6.	Uttarkashi distt	1 June 2011	One killed, Rishikesh-Yumnotri NH closed
7.	Joshimath, Chamoli	22 September 2010	Two killed
8.	Almora	19 September 2010	31 died and 7 injured
9.	Dehradun, UK	18 September 2010	NH for chardham yatra disrupted, tourists trapped
10.	Nainital	18 September 2010	Eight killed
11.	Pilkha and Devali villages	18 September 2010	Five killed 15 trapped, houses collapsed
12.	Avalbagh block, Almora distt	18 September 2010	Six killed 14 injured
13.	Rudraprayag	8 September 2010	One killed
14.	Pitthoragarh	6 September 201	Two killed
15.	Shumgarh Landslide, Bageshwar distt	18 August 2010	18 school student between 5 and 12 years of age were buried alive, 12 injured, whole school destroyed
16.	Chamoli	5 August 2010	Five killed, one house destroyed
17.	Uttarkashi	30 July 2010	Nine injured
18.	Almora distt	22 July 2010	One killed
19.	Nainital	20 July 2010	One killed
20.	Tehri distt	23 Feb 2010	Two killed one injured, one house demolished
21.	Uttarkashi distt	9 September 2009	Three killed, pilgrims and tourists stranded
22.	Almora distt	8 September 2009	Three killed five injured
23.	Almora distt	2 September 2009	Two killed
24.	Pitthoragarh	28 August 2009	One killed
25.	Pitthoragarh	17 August 2009	One killed

(continued)

Table 12.1 (continued)

Sl. No.	Location	Month/year	Damages
26.	Champawat distt, UK	17 August 2009	Two killed
27.	Nachni, Pitthoragarh	8 August 2009	43 killed, 3 Villages Nachni, La and Jhekla were completely buried under landslides
28.	Chamoli	26 June 2008	Eight killed two injured
29.	Rishikesh	20 June 2008	Ten killed
30.	Uttarkashi, Chamoli, Almora, Pitthoragarh and Champawat	29 September 2007	Four killed three injured, tourists/ trekkers and locals affected
31.	Nainital, UK	28 September 2007	One killed three injured
32.	Tehri distt	23 September 2007	19 killed 20 injured
33.	Pitthoragarh distt, UK	6 September 2007	14 killed
34.	Dehradun, Uttarakhand	17 August 2007	Seven killed, crops and houses destroyed
35.	Hat Kalyani, Deval	6 August 2007	Four persons killed and two livestock lost
36.	Chamoli, Pitthoragarh and Dehardun	27 July 2007	Three killed, several houses damaged, traffic disrupted
37.	Devpuri village, Chamoli distt, UK	12 July 2007	Eight killed
38.	Uttarakhand	4 July 2007	Five killed
39.	Uttarkashi district	26 June 2007	One killed
40.	Govindghat, Joshimath	August 2005	11 killed
41.	Vijaynagar, Rudraprayag	22 July 2005	Nine killed
42.	Varunawat Landslide, Uttarkashi, Uttarakhand	26 September 2003	About 400 houses/shops affected
43.	Budhakedar and Khetgaon Landslide, Bal Ganga Valley, Tehri	10 August 2002	29 people killed
44.	Khanera Landslide	30 August to 31 September 2001	Blocked Yamuna river, damaged a portion of the hill road upto a distance of about 150 m away from the bridge
45.	Dharchula	27 July 2001	Five killed
46.	Phata and Byung Gad Landslides, Chamoli	17 July 2001	21 killed and several houses damaged
47.	Ukhimath, Rudraprayag	16 July 2001	28 persons killed
48.	Earthquake induced landslides in Chamoli and adjoining districts	29 March 1999	Massive destruction
49.	Barua Bhenti slide UK	19 September 1998	15 people died, several livestock killed at about 8 km north of Okhimath along the left bank of Madhmaheshwar river

(continued)

Table 12.1 (continued)

Sl. No.	Location	Month/year	Damages
50.	Madhya Maheshwar, Rudraprayag	17 August 1998	40 persons killed and 10 livestock lost
51.	Banswara slide, UK	August 1998	Two persons died, 100 m road damaged about 25 km from Rudraprayag
52.	Malpa Landslide, Kali River	17/18 August 1998	Wiped out Malpa village with >210 persons killed
53.	Ukhimath Landslide blocked Madhyamaheshwar river (tributary of Mandakini)	12 August 1998	109 deaths and 1,908 families from 29 villages affected and 820 houses damaged
54.	Bhimtala Landslide	1996	Heavy damages to roads and houses
55.	Ratauri, Pitthoragarh	July 1996	16 killed
56.	Earthquake induced landslides in Garhwal Himalaya	20 October 1991	Massive destruction of houses, bridges, roads and other infrastructure
57.	Gopeshwar, Chamoli	16 August 1991	36 killed and 26 livestock lost in six villages
58.	Landslides at Jakholi in Tehri Garhwal and Devaldhar in Chamoli	1986	32 lives lost
59.	Kapkot, Bageshwar	August 1984	Nine killed
60.	Uttarkashi Kedarghati Landslide	1981	Houses and road damaged
61.	Ukhimath Landslide	1979	39 persons killed
62.	Dobata, Dharchula	19 July 1971	12 killed, 37 building damaged
63.	Belakuchi slide, km 259, UK	July 1970	Village Belakuchi and Belakuchi bridge washed away
64.	Chamoli district	20 July 1970	Landslide formed an artificial lake in the upper catchment of Alaknanda river; affected 101 villages, >100 persons killed and 142 animals died; about 36 vehicles drowned by flashfloods; district headquarter of Chamoli devastated and subsequently shifted to Gopeshwar
65.	Karnaparayag Landslide	1965	Damages to road and infrastructure
66.	Kaliasaur Landslide	1963	Damages to road and traffic blockade
67.	Nainital Landslide	1963	Damages to road and houses
68.	Patalganga Landslide	1945	Road breached and damaged
69.	Kaliasaur slide	1920	Road damaged (147 km on NH-58)
70.	Helang landslide	1906	Massive road damage occurred
71.	Landslide dam bursted at Gohna	1894	Breaching of Gohna Lake casued Birehi Disaster in Alaknanada valley
72.	Landslide blocked Birehi Ganga	1893	Landslide blocked the river and formed a lake at Gohna village in Garhwal Himalaya

(continued)

Table 12.1 (continued)

Sl. No.	Location	Month/year	Damages
73.	Nainital Landslide	1880	Massive destruction, killed >150 persons
74.	Landslide at Chamoli Garhwal blocked Alaknanda river	1868	Swept two villages and killed 70 pilgrims
75.	Landslide dam on Mandakini river	1857	Busrting of landslide dam caused loss of lives and properties
76.	Joshimath Landslide	1842	Damaged roads and blocked traffic
77.	Pauri Landslide	1816	Road damages and traffic blockade
78.	Earthquake Induced Landslides in Garhwal	1803	Garhwal earthquake affected about 80 % of the population

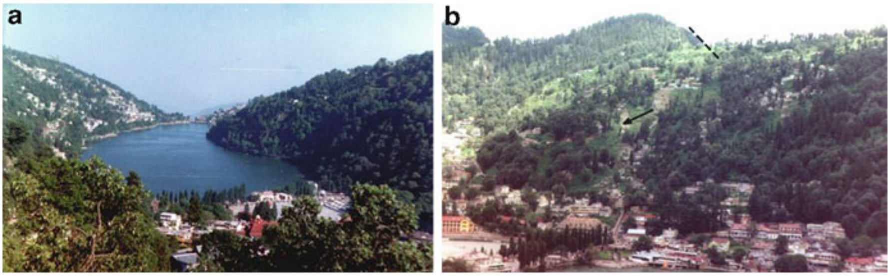

Fig. 12.2 (**a**) A view Nainital Lake with toe slopes at Sher-ka-Danda hill. (**b**) A view of Sher-ka-Danda hillslopes

12.2.2 Kaliasaur Landslide

The Kaliasaur Landslide (Fig. 12.3) is the chronic, complex, most persistent and regularly occurring landslide. It disrupts the entire life-line on the most important national highway leading to Badrinath and Kedarnath. It was reported first time in 1920, then in 1952, 1963, 1964, 1965 and a major landslide in 1969, 1970, 1971, 1972, 1985, 1987, 2011, and recently in 2013 after Uttarakhand flashfloods.

The landslide on the 19 September 1969 had blocked nearly three–fourths of the river, about 100 m below the road level. A 300 m stretch of the road was dislocated both vertically and laterally by about 2.5–3.0 m, and damage to the road structure was indeed severe. The slide was reported to have remained active for 4 days at a stretch. During 1970, 1971 and 1972, moderate to heavy landslide activity was witnessed. In the process, the communication system was disrupted, and each time there was a new formation a width for road had to be cut. During September 1984, following heavy rainfall, the landslide became violent and damaged the road

Fig. 12.3 A panoramic view of Kaliasaur Landslide

considerably, extending the rear scar of the landslide retrogressively. The recurrence of August 1986 was equally severe. The total area of the slide, above and below the road level together, measured 86,000 m^2 at that time.

The rocks are mainly white and light green quartzite inter-bedded with maroon shales and the massive well-jointed yellowish white quartzite. On the western side of the slide zone, the quartzite is light green with shale bands having a general southward dip ranging from 25° to 60°. These quartzites end up abruptly along a scree zone beyond which massive yellowish quartzile is exposed, dipping 30–40° south–east. It appears that the scree zone conceals a fault zone trending NE–SW and extending across the Alaknanda river. The massive quartzites continue up to the western flank of the slide zone where they end up against the slide debris. On the eastern side of the slide zone, the quartzites exposed have maroon shales with a southeastern dip varying from 30° to 60°. The quartzites continue along the riverbed. It appears that another fault zone trending NW–SE may be present somewhere within the slide zone.

The rocks appear to have been folded into a plunging overturned anticline on the western side of the slide zone with a plunge towards the northeast. Another anticline appears to be on the eastern side of the slide zone with a plunge towards the south.

In this area, river Alaknanda occupies a deep sinuous gorge with the crest of sinuosity located near the slide zone. The slopes on the left side of the river are steep whereas they are rather gentle on the right side. The slide zone is located on the left side of the river, which supports the main road. This area contains a number of smaller scree zones, along with areas where quartzites are exposed. There appears to be a significant escarpment running east-west below the Chhantikhal village. This escarpment continues up to the riverbed. The lower part of this escarpment is occupied by colluvium resting nearly at its angle of repose. The middle part exposes quartzites, and on the top field cultivation can be seen. Above this escarpment, the vegetation is thick. There are a number of small streamlets flowing over the escarpment, eventually joining the river at a steep gradient.

Kaliasaur landslide is essentially a multi-tier, retrogressive landslide in a complex rock formation with clear evidence of fault planes testifying to the intense tectonic activity in the geological past. There appears to be a number of fault zones in this area. A major fault appears to trend east–west. This fault zone passes through the crest of the slide and separates the metabasics from the quartzites. Two other faults trending NE–SW also exist in this area. They all appear to be high angled and one of these passes through the main slide zone. All these faults probably merge into Chhantikhal fault.

Evidence of sliding at the interface of quartzites and maroon shales must presumably have been the starting point. Road construction activity in general and repeated back cuttings required for restoring the road width, year after year, combined with poor drainage to create recurring debris slides in the colluviums cover. The river action at the slope toe aggravated the instability.

The remedial measures included grading of the slope, uphill of the road, sealing of tension cracks and fissures on the slope surface, timber piling to stitch the colluvium on the slope, construction of an anchored drum diaphragm retaining wall along the road to support the slide mass overlooking the road Construction of an anchored stone masonry wall towards the other side of the road to check the under cutting of the road due to palaeo-channels, vegetative turfing of the slope and construction of a toe wall in masonry at the junction of the slope down hill of the road and the river. This wall was designed to withstand the scour of the river.

Driving of timber piles made the loose and shallow granular slide prone carpet on the slope dense and provided the ‘stitching action’. Timber piles 10 cm^2 from Deodar, Sheesham and Eucalyptus wood were driven in lengths of 1.5 m each suitably spliced. For a multi-tier slide like the Kaliasaur, the vegetation by itself will not be meaningful unless used in conjunction with other remedial measures.

12.2.3 The Alaknanda Tragedy

One of the most severe landslides occurred in 20 July 1970, along the river Alaknanda, in Uttarakhand Himalaya. The trend and impact of new and old landslides, the aggravating slope toe erosion due to serpent like rivers, the silt swollen riverbeds, and the consequently choked bridges, the sinking roads, the nasty road and river blockades.

During this period of 1–20 July 1970, rivers Alaknanda and Dhauliganga both reportedly carried a heavy charge of debris contributed by widespread landslides and primed by the rainfall of 126.5 mm, recorded at Joshimath. Then came a pause in the rain. From 8 a.m. on the 19 July to 8 a.m. on the 20 July, only 14.1 mm of rain occurred, and that must have surely taken the force out of the sediment carrying power of the sediment saturated Alaknanda. That is how the huge amount of debris must have been off-loaded by the rivers of the valley choking their courses, especially where the river bends were narrow, like the one at Patalganga (Fig. 12.4), or that between Vishnuprayag and Pakhi. This pause in rainfall was quickly followed in succession, by an all time high rainfall of 212.0 mm between 2 p.m. on the 20 July and 8 a.m. on 21 July (i.e. in about 20 h), surpassing the previous maximum of 200 mm.

The cloudburst prompted river Patalganga to move a huge pile of debris discharged by river Patalganga drove river Alaknanda to its right bank, choking it badly. Soon Patalganga itself got blocked at its constriction. Thereafter, the water level began to rise rapidly. The shifting of Alaknanda to its right bank created a situation identical to the one usually found in the middle of a meander. A massive blockade also occurred on the Karamnasa nallah near Helang.

At 6 p.m. immediately upstream confluence of the Patalganga and Alaknanda, the water level rose by 45.7 m within just 45 min. The breach of the landslide dam occurred at about 6.45 p.m. and the next one an hour later and this turned out to be perhaps the most devastating (36 h) in the known history of the area. Upon breach of the landslide dam, the highest water level mark, seen between km 256 and km 253, left clear marks of the abnormally high water impounding. The impounding led to the deposition of thick masses of debris on the road. One view is also that when the Patalganga landslide dam burst, another dam was created by debris so released in the already narrow channel of Alaknanda. This, however, seems less likely because the bursting of a dam is usually accompanied by a tremendous amount of energy release, usually enough to flush out the debris.

12.2.4 Malpa Rock Avalanche

It was at about 0025 h on 18 August, 1998 when a thunderous noise woke up the inhabitants of the village Malpa, situated on the right bank of the river Kali, in the district Pithoragarh, Uttarakhand Himalaya. A huge mass of rock got detached from

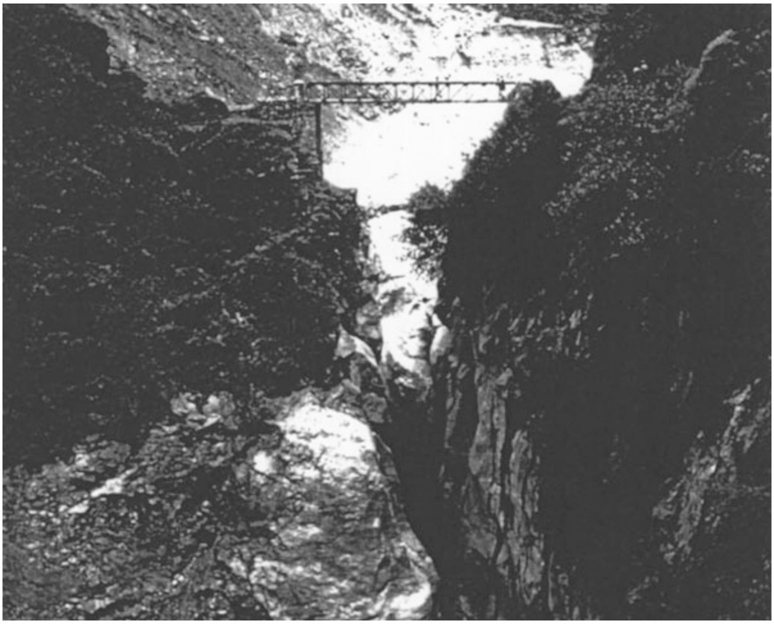

Fig. 12.4 A rare catastrophic landsliding and flooding in Alaknanda river

the head region of the parent rock, broke into a number of pieces, and hurtled down the slope (Fig. 12.5). The detached part of the rock mass generated a spectacular and huge rock avalanche, bright flashing light and sparks on the upper slopes, and a dust storm (Bhandari and Kishor 2000). The rock avalanche so generated eventually came to rest but not before killing 270 people including 60 pilgrims. The heaps of debris so created were about 15 m high, and these included rock fragments as big as 5 m. The estimated velocity of the avalanche in some of its reaches was 30 m/s. Before the disaster, the hit the slopes surrounding Malpa village, it looked green, virtually without any visible signs of instability.

The clear symptoms of instability were, however, ignored because the people of Malpa, over a period of years, believed that the thunderous sound and falling of boulders down the slope were quite normal happenings, seldom to be taken seriously. The appearance of light flashing on the higher slopes may possibly be explained in terms of (1) release of static electricity upon fracturing and tearing away of the rockmass in the detachment phase of the rock avalanche (2) the impact of falling rocks and their collision and attrition during motion. Also, such phenomena are rarely reported because most avalanches occur in wetter slopes, and it is the dry slopes which usually provide an ideal setting for frictional sparking and fire. The speed of the slide was reportedly so high that the flying rock masses rammed with one another, acquiring velocity up to 40 m/s. The lithology of the area around Malpa represents an intricate system of folding, thursting, metamorphism and igneous action. The great Himalayan belt of Kumaon is occupied by

Fig. 12.5 Post-disaster view of Malpa Landslide site

Pre-Cambrian metamorphites of Central Crystalline with isolated, but sizeable amounts of metasediments, gneisses, augen gneisses, streaky gneisses, schists, granites, quartzites and amphibolites. The slopes are generally high and sleep (60″–70°), and the rocks of the region are fractured. The Main Central Thrust (MCT) is known to pass through Budhi, only 8 km from Malpa. The avalanching rock mass at Malpa consisted of fragments of massive quartzite inter-bedded with a thin band of garnet bearing sericite schist. The freshly exposed rock faces of the hill show a series of parallel foliation planes and near vertical joints, striking perpendicular to the foliation plane.

This was the first time landslide occurrence in that area. The mountain slopes were generally high and steep and the rocks were of fractured nature. River Kali passes along this rock bed and that perhaps caused widening of the rock fissures. The river water thrust on the fractured rock and the drainage, and the excessive construction work together were the major contributing factors for the avalanche.

12.2.5 Bheti-Paundar Landslide

In August 1998 so many small and big landslides occurred which took a toll of 107 casualties and heavy loss of property in 29 villages of Okhimath tehsil, Chamoli district. Bheti-Paundar landslide (Fig. 12.6) had totally demolished the Bheti, Paundar and Sem village situated on the other bank of the Madhyamheswar

Fig. 12.6 A panoramic view of Bhenti-Paundar Landslide

Ganga, and created an artificial lake due to the blockage of Madhyamaheswar Ganga river course for about 24 h.

Gully erosion and toe cutting by the drainage is very much predominant in this area. Slopes from both the side of landslide zone washed out by the hydraulic action. By viewing the landslide scarp it could be assumed that this is the result of rotational and translational failure of slope. So, it is registered after calculation that the volume of debris at source is higher than the volume of debris deposited at fan. It is assumed that the rest of amount was swept away by the river or rain.

As a result, the carrying capacity of the river was reduced and the area covered by thal-weg was increased and then the chances of flooding had increased. At the time of 1998 event it was noticed that the huge amount of debris from the slope blocked the flow of Madhyamaheswar Ganga which created an artificial lake on 19th August.

It is recommended that the valley side slopes should be planted with local varieties of stabilizing plant by the local community or by village panchayat.

12.2.6 Phata-Byung Landslide

The landslide of 16 July, 2001 was also a deadly event along the Guptakashi-Kedarnath route, NH 109, District Rudraprayag. The two landslides, Phata and Byung (Fig. 12.7) were the two separate major events that occurred in the area,

Fig. 12.7 Phata Byung Landslides on Guptkashi–Kedarnath road

where more than 200 landslides were experienced on that day. In these landslides a total of 27 persons left dead.

The area consisting of low to medium grade crystallines with intrusive of acidic and basic rocks. The rock types of this area are garnetiferous mica schist, granite gneiss, porphyritic gneiss, talc-sericite schist, schistose quartzite, marble and amphibolite. This area is traversed by two major thrusts, namely Main Central Thrust (MCT-II) which passes below the tragedy area at Kund, and the Vaikrita Thrust (MCT-I) which passes above the area from north of Gaurikund. MCT is a nearly 10 km wide shear zone, inclined at 20–45° northward. A number of fracture zones parallel or oblique to the thrust have also been observed. Three types of slope failures were observed: debris slide, block slide and rock-cum debris slides. These are mainly due to planar, wedge, translational or rotational failures. At Rail, Tarsali, Lolchhara, Semkurala and Dhani, the failures are mainly joint controlled and slip has commonly taken place along dip, strike and oblique joints.

Usually strike joints are more vulnerable and indicate failure along bedding planes, whereas dip joints suggest failure along fold axes. Vulnerability of strike joints may indicate influence of a strike slip fault. The strike joints generally have an east–west trend with 60–75° dip towards south and the dip joints have mainly north–south trend with 55–65° dip towards west, whereas oblique joints have NW–SE trend with 20–25° dip towards NE and NE–SW trend with 70–75° dip towards west. The intersection of two or more joint planes is marked with wedge failure. Slopes under small agricultural fields with thin soil cover, characterized by two or more sets of joints, were ravaged by the translational slide. Debris flows were common along high gradient tributary streams, the channels of which are narrow. The rotational slips, generally triggered by high pore water pressure, are developed along deeper slip surfaces where thickness of the regolith is 10–50 m or more. Slumping is also reported where the thickness of regolith is more and the basement is cut by some channels. Majority of the debris slides is confined to the mica schist and amphibolites, due to highly fractured and jointed nature of the bedrocks and presence of shear zones and other structures.

The landslides and rockfalls that wiped out fifteen villages of this area, in the inner belt of Central Himalaya are not uncommon phenomena. They occurred in the hazardous zone with active faults, and were of predicted severity and proportion. A detailed survey of the area has revealed that 52.67 km^2 of the area received very heavy precipitation. The losses assessed by us and local government agencies are: 27 human lives, 64 heads of cattle, 22 houses and 43 ha of agricultural land. In all, 15 villages and 3,924 people were affected. The road along the Kedarnath–Guptkashi segment suffered maximum damage and the major disaster was at Phata Market and along the Byung stream.

A combination of factors appears to have contributed to the present tragedy. This area is tectonically and seismologically a very sensitive domain. The strong tectonized rocks and the fragile mountain slope of the MCT zone in this area are vulnerable to rain, earthquakes, vibrations due to movement heavy vehicles, excavation work, etc. The MCT that has tectonically subdivided this area into three different zones, is characterized by the presence of fractured rocks and is thus, particularly vulnerable to extensive erosion and frequent failure. A large number of catastrophic landslides reported from this area, indicate of the presence of a number of fracture zones. The area lies in the seismic zone V. The recent seismicity of the Garhwal region reveals that a 5.0 magnitude earthquake had occurred in this area in 1996.

The present area falls in the zone of very high precipitation. In such a zone, 200–500 mm of rainfall can be expected in 1 day, once in every 100 years. There were incessant rains 1 day before this incident. Whenever the drainage density is high, the running water washes out the cohesive material from the soils and rock masses. The water pressure not only pushes the slope material forward, but also generates pore water pressure along joints and bedding planes.

As the failure starts, the opening of rough joints is enlarged on dilation. Thus, the sliding plane acts as a natural channel for the flow of water. The secondary structural weaknesses present in the host rocks and pre-existing slip-surfaces in old landslide areas are also reactivated. Because of adverse hydrological conditions at higher reaches, active creeping and subsidence are also observed. Particularly in the Byung landslide a formation of waterfall in the upper reaches of the landslide scarps can be seen. It is due to the underground seepage of water from the upper side of hillock. This waterfall is fatal during the monsoon season and continuously damaging NH 109. The slope is vertical and continuously eroded by the hydraulic action of water.

So a combination of several factors like tectonically disturbed and fractured lithology of the MCT zone, seismic events, loose soil cover, solifluction lobes on steep slope and prominent seepage zone are responsible for this tragedy, but the action of water during the torrential rain appears to be the main triggering factor.

Many villages in this area like Dhani, Jamu, Semkurala and Talla Khumera may be washed away in the next rainfall. Hence people, livestock, etc. need to be shifted to safer places.

There is also an immediate need for identification of areas which are relatively more vulnerable to landslides and mass movements. Then, there is need to curb

Fig. 12.8 A partial view of La-Jhekla Landslide

future construction and if allowed only after detailed studies of local stability of terraces and the evaluation of terraces and the evaluation of the geotechnical parameters of the allowable bearing pressure of the slope material. Buildings construction practices over solifluction lobes, landslides debris and MCT escarpment in this region should be stopped. Public awareness programmes to train people to cope with this problem and situation, must be initiated.

12.2.7 Tragedy of La-Jhekla

The landslide (Fig. 12.8) occurred on 8 August 2009, which wiped the villages of La and Jhekla claiming 43 lives is considered one of the worst tragedy for Kumaun region in recent times. The landslide triggered by cloud burst resulted in massive debris flow along a stream channel.

The slide was triggered by a cloud burst which caused massive debris flow along the stream called 'Paniyal Gad' and after destroying the road and the villages deposited on the downhill slope below the road were completely ruined. The debris came down from the higher reaches of 'Paniyali Gad' and after destroying the road and the villages deposited on the downhill slope. The impact of debris flow was so intense that, within no time, all the residents of the villages were buried under a thick pile of debris.

Rocks exposed in the area are primarily dolomites. These rocks are degraded by intense fracturing and shearing due to the tectonic activities and subjected to severe erosion by the streams continuously eroding and dislodging rock boulders and rock fragments along with water saturated soil mass.

Many landslides are observed in the surrounding region. A major landslide was observed on the higher slope on the left bank of the Jakula river while the present landslide occurred on the right bank of the river. These indicate that the area is very susceptible to landslide occurrences.

The main escarpment of the landslide was developed at height of about 80 m above the road level and at a sloping distance of about 200 m. This is a rough estimation as the crown section of the slide was not clearly visible. There are many secondary scars along the stream which were developed due to the impact of debris flow and erosion by the rapid water flow along the channel. The debris moved down along the narrow path in a 10–15 m wide channel. The toe of the slide at river level has a thick pile of debris deposited in a fan shape on a gentle slope. The debris volume resting on the downhill slope is estimated to be of the order of 200,000 m^3.

The flow direction is 130°N along the hill slope. The average slope angle is about 20–25° above the road level while the debris resting on the slope below the road is about 30°. The right flank of the slide along the channel has fractured and jointed rocks dipping 25° towards 20°N. The slope is very steep on the right flank. On the left flank, the slope has agricultural land having a general slope angle of 20–30°. The slope has a thick soil cover with occasional rock outcrops. Numerous ground cracks have developed on this slope due to the landslide. The cracks are transverse and longitudinal and a few of them are visible up to 1 m deep and 40–50 cm wide.

The prime cause of the landslide was an unprecedented heavy rainfall. It seems that the slope before the slide must have been in a marginally stable condition due to erosion by the stream, weakening the weathered geological strata overlain by loose rock boulders. The other preparatory factors could be the neo-tectonic activities as the area is close to MCT.

As observed from the Bhuvan satellite image of pre-landslide scenario of the area, it is inferred that a landslide escarpment existed on the upper reaches of the Paniyali Gad stream. The stream flows towards NE direction up to the road level and changes its direction towards east below the road level. Before meeting Jakula river, the stream gets bifurcated into two different channels. La village is situated close to the river bed between these two channels and Jhekla village is situated on the northern side/left flank of the Paniyali Gad stream just below road level.

From the field observation, it is inferred that the slide might have been situated with the dislodging of loose overburden material saturated with water and scouring of adjoining slopes producing a huge quantity of debris after the heavy downpour. The accumulation of debris in the narrow channel may have blacked the channel for a short duration creating very high hydrostatic pressure. This could have resulted in complete failure of adjoining slopes, adding more debris which ultimately flowed down with the water along the narrow channel. Because of the confined narrow channel with a 25–30° slope carrying a huge amount of debris in the form of slurry, the flow occurred with a very high velocity and further eroded the left flank of the stream above the road level. The water charged with enormous quantity of debris could not deposit its load till it reached the road level after which the debris spread on the downhill slope. This can be very well explained by the morphology of the slide area which indicates that there is a topographic control over the landslide process and damage.

As the debris reached the road level it again started flowing down the slope in the form of the debris and mud flow while depositing part of the debris on the way down the slope. In this process the debris washed away Jhekhla village located just below the road. Further down slope, the debris flowed and deposited as a fan engulfing La village before reaching the river level.

The presence of huge debris along the stream and below the road and the ground cracks on the uphill slope has indicated that the area is still under considerable risk to life and property. Such a type of massive landslide hazard cannot be prevented, but the consequences can be minimized if there is proper risk estimation and planning prior to such a major event.

With the help of high resolution satellite data, source zones of these landslides can be identified and terrain features along with geo-morphological characteristics may lead to assess the debris flow hazard. The risk elements which are essentially the lives, buildings, roads and other property can then be evaluated to determine the risk from these landslides.

A dense network of rainfall station should be installed particularly in the areas with a past history of cloudburst. Monitoring rainfall, landslide warning can be transmitted to landslide-prone areas with high risk during heavy downpour. After discussion with the locals, following points emerged:

- In the La village, the dead bodies of persons and animals could not be recovered despite all possible efforts. Because the thickness of debris was about 8–10 ft and because of swamp it was very difficult to work. Only available rescue equipment were spade, Gaiti, Belcha etc. Had the pressure pipes available, perhaps some debris could have been cleared and dead bodies be recovered.
- No-housing construction zone should be marked clearly.
- Jhekela and La villages are situated near Sukalya nala which caused lot of damage. During rainy season even dry Nala take threatening shape. The survived families should be rehabilitated to safe areas.
- Mitigation programmes should be undertaken. Awareness programmes should be arranged against earthquake land slide and cloud burst problems.
- Good communication system in not available in the area and primary health centres also are very far away.
- Survey/feasibility of helipad construction in the area should be considered.
- Special training in search & rescue in swampy areas to the rescuers to meet such exigencies. Proper equipments are also essential for the rescue teams.
- Awareness and capacity building programmes to the locals before Monsoon Season for weather induced hazards should be undertaken.

Fig. 12.9 A view of Primary School hit by landslide where 18 children were buried alive

12.2.8 Kapkot Landslide

A major landslide occurred on 18 September, 2010 hit a private primary school, Saraswati Shishu Mandir, at Sumgarh Village, Tehsil Kapkot in Bageshwar district where in 18 children of Classes I and II were buried alive under rock debris. Over 25 children got severely wounded (Fig. 12.9).

Numerous landslides, land erosion and subsidence occurred at different places of district Bageshwar during the month of September 2010 initiated by heavy rainfalls and cloud burst disaster caused 19 human deaths, widespread damage to human settlements, cultivated lands, irrigation canal, bridge, village foot tracks and major communication routes. More than 50 major landslides classified as rock slide/fall, debris slide, rock-cum-debris slide, and slope wash debris flow and bank erosion of different nalas/streams have been recorded.

12.3 Key Lessons and Implications

The paper attempts to summarize the key lessons drawn from the different landslide events mentioned above and highlights the main points that should have some implications in policy, planning and decision making for management of landslides in the state as well as other areas with similar situations. Table 12.2 provides this summary below.

The table briefly provides only 2–3 main points pertaining to each of the disaster discussed in this paper. However, there are complete documentation reports and

Table 12.2 Landslide Events, Key Lessons and Possible Implications of Policy, Planning and Decision Making for Landslide Risk Reduction

S. No.	Landslide Event	Some of the Key Lessons drawn from the event	Possible implications on policy, planning and decision making for landslide risk reduction
1	Sher-ka-Danda Landslide	• Continuous heavy precipitation over unstable slopes and loose/ unconsolidated materials like fluvioglacial deposits may result in significant landslides	• Adequate rainfall observation and monitoring system is necessary
		• Development of cracks and infiltration of water into the slopes may endanger the stability of hillslopes	• Local community should be sensitized and made aware about the likely impacts of landslides o their buildings
		• Construction of buildings and deforestation in such places should be avoided	• Landuse regulation and control policy should discourage concentration of population in landslide prone areas and restrict/ prohibit building and road construction on such slopes
2	Kaliasaur Landslide	• Landslides can be complex and chronic problems	• Alternate route alignment should be planned for unavoidable landslide prone areas for timely evacuation and response during any disaster
		• Traditional investigation and remediation works may not be able to control complex chronic landslides	• Innovative scientific and technological means should be considered for landslide sites where traditional methods do not work
		• Adequate timely interventions are pre-requisite for reducing the risks	• An alert and warning sign board should be kept on roadside to instruct people to watch for landslides while they cross such spots
3	Alaknanda Tragedy	• Any drastic changes in the normal river water levels must be carefully noticed	• Adequate system of monitoring river water discharge may be made mandatory
		• Blocking of river or its tributary due to landslides can lead to formation of temporary lakes and bursting of such transient lakes may bring huge devastation on downstream side	• Transient lakes formed by landslide dams may be breached under controlled supervision of experts
			• Community should report to the state authorities if any such blockades are observed
4	Malpa Rock Avalanche	• Site conditions must be carefully considered, particularly for potential landslides while erecting tents or temporary shelters in the hilly terrains	• The department of tourism, trekking and adventure activities must prepare the concerned stakeholders about the potential disasters in the hills and inform them about the actions to be taken

(continued)

Table 12.2 (continued)

S. No.	Landslide Event	Some of the Key Lessons drawn from the event	Possible implications on policy, planning and decision making for landslide risk reduction
5	Bheti Paunder Landslide	• Residents must keep a watch on slope conditions, particularly during the rains	• Building construction regulation may enforce adequate protection measures around houses to reduce the landslides risks
		• If any cracks are observed, these should be properly sealed to reduce the infiltration of water into unstable slope mass	• Preventive measures must be implemented timely to reduce probability of exposure to landslides
		• Adequate protection measures around the buildings may reduce the landslide impacts	• Community must be informed of any impending danger of slope failure
6	Phata-Byung Landslide	• Weak rock masses dissected by geological structures like joints, faults and thrusts pose threat of landslides	• Geological conditions i.e. the presence of joints, faults and thrusts that may pose risk to the people, must be well mapped and informed to the residents
		• Construction of houses over weak rock masses must be restricted	• Adequate strengthening and grouting measures must be followed before doing construction over weak slope masses
		• Quick response teams should be kept ready during rainy season to help people during disasters	
7	La Jhekla Landslide	• Mushrooming of temporary shops and buildings close to roadsides near river tributaries could be dangerous	• People must be warned about the potential dangers of landslides, debris flows and flash floods, particularly when they are living close to river or its tributary and in the vicinity of the upper areas that receive intense precipitation
		• Intense rainfall in the upper reaches may lead to debris flows and flash floods on the downstream sides	
8	Kapkot Landslide	• Educational buildings must be carefully located to avoid the impacts of landslides	• School safety plans must be prepared and enforced
		• Quick and timely evacuation of buildings must be ensured before the disaster strikes	• Training and capacity development of the different stakeholders must be ensured
			• Regular/periodic mock drills and exercises must be planned

memorandum by concerned department and agencies that bring out significant number of issues related to policy, planning and decision making for reducing the risks based on the lessons learnt from these events.

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