The Problem of Landslides

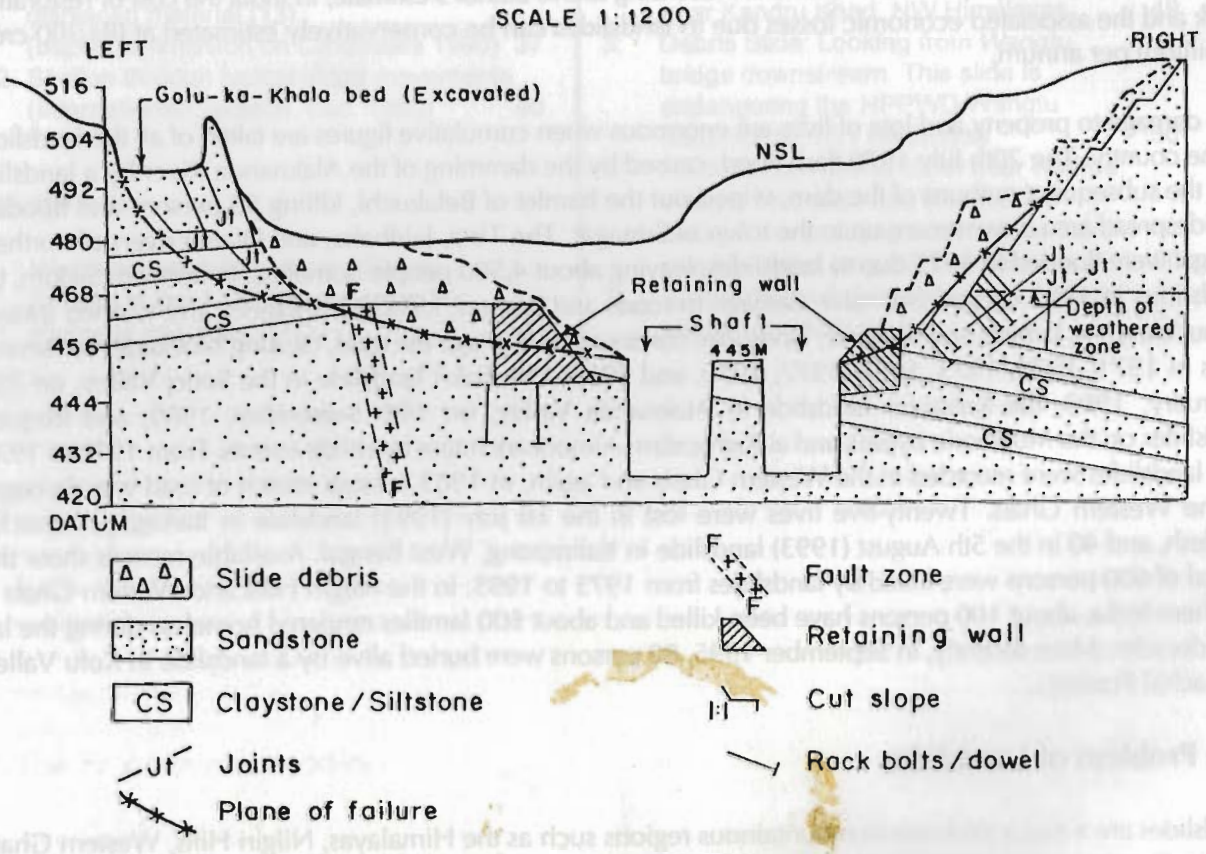
Landslides are a major problem in mountainous regions such as the Himalayas, Nilgiri Hills, Western Ghats, and northeastern region in India, disrupting communication routes, increasing the sediment load of rivers, and resulting in additional expenditure for the state exchequer on landslide control. Landslides take place most frequently during the monsoon rains, as water is an important catalyst for initiating landslides. In the Himalayas, the winter rains and, at high elevations, frost action and snow also contribute to landslides. Inherent geological characteristics of the strata and geometry of the slope control the stability of the slope and, in turn, landslides. Active tectonic movements; such as the movement across faults and uplift of topography, occurring at a rate of 20mm to 50mm per year in the Himalayas; result in weaknesses across certain tectonic zones that are prone to extensive landslides and other types of mass movement. Deforestation, as a result of the felling of trees for timber, and removal of vegetation cover, as a result of development activities such as building roads, dams, and settlements, are also responsible for the increased rate of soil erosion and destabilisation of slopes prone to landslides.

In India, a fairly good network of roads has been constructed in the Himalayas and in the hill states of the Northeastern region in the last five decades. There is also a good system of roads and railways in the Western Ghats and Nilgiri Hills. Disruption of traffic is very common, especially during the monsoon months, and, sometimes, vehicular traffic is blocked for several days as a result of landslides.

There are several instances of landslides being a major problem in the construction of major hydroelectric projects in the Himalayas. Case histories of landslides affecting power projects, such as the Chineni hydel project in Jammu and Kashmir, the Baira-Siul and Giri hydel projects in Himachal Pradesh, and the Beas dam project at Pong in the Punjab, have been described (Krishnaswamy and Jain 1975). In all these cases, control measures were successfully adopted on the advice of geotechnical experts from the Geological Survey of India.

The case history of the powerhouse slide of the Giri hydel project in Himachal Pradesh is illustrated in Figure 1 as an example. During the excavation of the powerhouse pit of the Giri hydel project, landslides occurred, as anticipated, on both the slopes. To stop the sliding, several control measures were suggested, including the construction of a reinforced concrete (RCC) retaining wall; easing of slopes, 1:1, on either bank of the Golu Ka Khala; and, later, grouting and shotcreting the slope faces and rock bolting.

Figure 1: Geological cross-section across Golu Ka Khala Powerhouse area, Giri Hydel Project, H.P., showing geology and control measures (Krishnaswamy and Jain 1975)



There are several instances of the damming of rivers by landslides and subsequent outbursts of the dams, resulting in heavy destruction in downstream areas. This generally happens when a side stream joining the main river suddenly brings a large amount of debris as a result of cloudburst. There have been numerous such outbursts of landslide dams, e.g., the Gohna landslide dam in 1893; the Reni landslide dam in 1968; the Belakuchi landslide dam in Garhwal in 1970; the Parachu landslide dam caused by the Kinnaur earthquake in 1975; and the Jhakri landslide dam across the Sutlej River in Himachal Pradesh in 1993. Making a passage for the river by breaking or partly blasting the way out from the dam is the best way of averting disaster downstream, and this was successfully accomplished with the Jhakri landslide.

Environmental Impact of Landslides on Urban Settlements

Several hill stations were built by the British in India's Lower Himalayan regions, e.g., Dalhousie, Dharamsala, Sigla, Mussoorie, Nainital, and Darjeeling. These hill stations have now grown into medium to large urban settlements and have witnessed rapid growth in recent years. All these towns are located in areas that receive a minimum rainfall of 2,000mm per annum. Landslides and subsidence are an acute problem in Nainital and Simla, but the problem is not so acute in Dalhousie and Dharamsala because of their favourable topography;. the frequency in the latter two urban areas being on average one major landslide in one area every two to three years. Landslides and subsidence in Simla and landslides in Nainital are described below.

Landslides and Slope Stability in Nainital

Nainital is an important hill resort in the Kumaon Hills of Uttar Pradesh. It has a natural lake at an altitude of 1,929.2masl. The lake is two kilometres long and one kilometre wide and is surrounded by hills ranging in height from 2,085m to 2,612m. The hill slopes, in general, are scree strewn and have abundant pine trees. Nainital lies at the southeastern end of a synclinal basin, predominantly comprised of limestone-dolomite, shale-quartzite, and conglomerates of the Krol Group. The overburden is of Recent to Subrecent deposits. The rocks are highly folded and faulted, with a major thrust in the area called the Manora Thrust. The Main Boundary Thrust also passes south of Nainital. The recurrence of large landslides and slips has been seriously limiting the growth of the township, and, in some instances, large infrastructures, such as hotels and buildings, are threatened by landslides. Nainital's local economy is totally dependent on tourism. The further development of tourism infrastructure is constrained due to slope instability. The Nainital Lake, which is the heart of the hill resort, is receiving an increasing sediment load from landslips and landslides, threatening its very existence.

The Sher-Ka-Danda slopes and the Kailakon Balia ravine are the active slide areas in Nainital. The presence of a 1.25km long crack along the slopes of Sher-Ka-Danda, extending from Government House to the Birla Mandir area, has been reported since 1897. Horizontal movement of 1.5m, between 1957 and 1965, was observed on either side of the Sher-Ka-Danda hill cracks. In the Kailakon area, a maximum horizontal cumulative movement of 35m and a cumulative vertical movement of five metres have been recorded in the last 60 years. The annual rainfall varies from 2,600mm to 2,900mm, of which 2,400mm occurs during the three monsoon months. It has been observed that landslides and subsidence occur mainly during the monsoon months. A landslide hazard zonation map showing different areas of instability in Nainital township and Balia Valley is shown as Figure 2 (Valdiya 1987).

Subsidence and Slips in Simla, H.P.

Simla, summer capital of British India and now the capital of Himachal Pradesh state, is located on a ridge at an altitude of 2,012m in the Lesser Himalayas. The area receives an average annual rainfall of 1,600mm, most of which is received during the monsoons. Although small slips and subsidence have been common occurrences, a major subsidence occurred along the ridge in August 1971, following heavy precipitation. The fissures formed by subsidence extended for over 400m in length, showing a vertical displacement of half a metre.

Investigations carried out around the town by the Geological Survey of India (GSI) revealed the presence of a funnel-shaped mantle of overburden with the upper rim of the funnel coinciding with the northern edge of the ridge; most of the portions affected by slips and subsidence lie within the overburden funnel. Control measures carried out included drainage construction to prevent percolation of the surface water into the overburden, and there was no new construction on the affected portions of the hill slope.

Simla, being the state capital of Himachal Pradesh, has witnessed accelerating growth in the last few decades, and it has grown from a town to a city. The thick forest cover of *Deodar* trees on the hill slopes was cut in many places to construct office buildings, houses, and hotels, thereby degrading the hill slopes and triggering landslides. The main reason for the landslide problem in Simla is the poor planning and bad implementation of construction projects without giving due consideration to geological and ecological conditions.

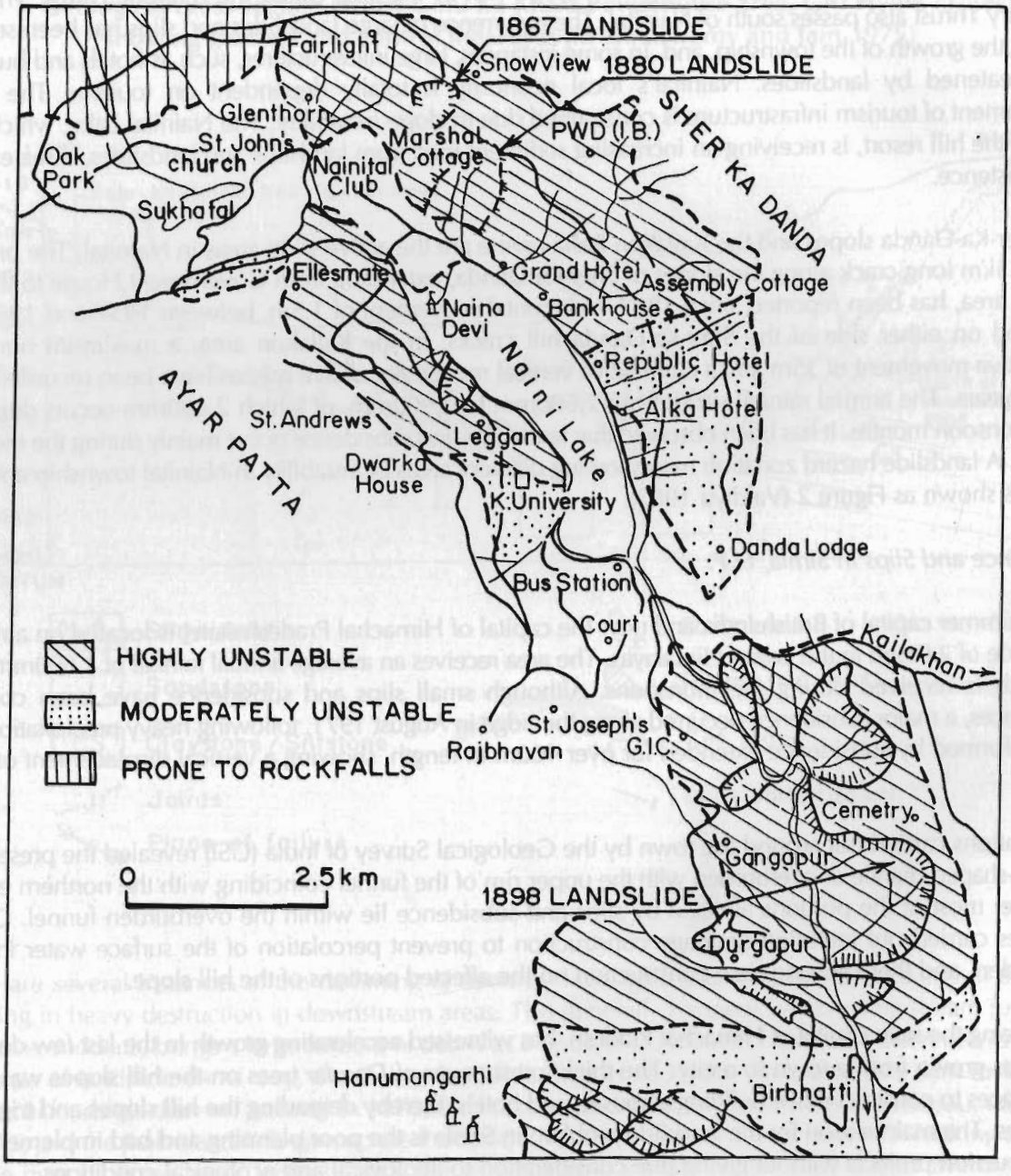
The Landslide Problem in Mussoorie

Mussoorie is another hill station built by the British, located 260km NE of Delhi, at an altitude of 2,000m. The landslide problem here has been triggered by the unabated growth of poorly planned hotels and commercial establishments, which has considerably reduced the vegetative and forest cover of the hill slopes.

Impact on Farms and Agriculture and Infrastructure

The loss of farm and agricultural land as a result of landslides is negligible and often not reported in the Indian Himalayas. However, some villages and farmlands are located on geologically old landslide soil on hill slopes, especially on Lesser and Higher Himalayan terrain.

Figure 2: Major instability zones in the Nainital town slide and the Ballia Valley (Valdiya 1987)



Roads are the most vulnerable infrastructure prone to landslides in the hills. About 90 per cent of landslides occur during the three monsoon months, and the rest (about 10%) take place during the winter rains. In September 1995, there were very heavy rains in the Kulu and Chamba valleys in Himachal Pradesh, severing communication links for about 10 days due to heavy landslides. The maintenance expenditure on landslides and for keeping roads open to vehicular traffic costs the government exchequer approximately 100 *crore* rupees per year for the Himalayan region only.

Other infrastructures that have been affected by landslides are bridges, dams, and powerhouses; but they are mostly only threatened, and remedial measures have been taken to save them. Therefore, it is very important for the major engineering projects in the Himalayas that proper assessment of slope stability is carried out and remedial measures taken in advance to prevent major landslides. Examples of such hydropower infrastructures threatened by landslides have been reported at the Sanjay *Vidyut Bhaba* project in the Sutlej Valley and at Uttarkashi in the Bhagirathi Valley.