Annexure-1

Report
on

PREPARATION OF LANDSLIDE HAZARD ZONATION MAP OF DHARAMSALA TOWN AND ADJOINING AREA, DISTRICT KANGRA (H.P.)

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March 2000

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Ref. No. Endst/281/MA, dt.27/2/99

Title of Project: PREPARATION OF LANDSLIDE HAZARD ZONATION MAP OF DHARAMSALA TOWN & ADJOINING AREA, DISTRICT KANGRA (H.P.)

Report Period : March, 1999 to March, 2000

Name of Investigators : Dr. A.K. Mahajan

Dr. N.S. Virdi

Team Member : Dr. Surya Parkash, Research Associate

Submitted to

Deputy Commissioner, Kangra at Dharamsala
Himachal Pradesh Government

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PREPARATION OF LANDSLIDE HAZARD ZONATION MAP OF DHARAMSALA TOWNSHIP & ADJOINING AREA, DIST. KANGRA, H.P.

PREAMBLE

The Deputy commissioner, Kangra at Dharamsala, vide his letter no. Endst. No. 281/ MA dated 27/2/99, requested to the Director, Wadia Institute of Himalayan Geology, Dehradun to prepare the landslide hazard zonation map of the Dharamsala town and adjoining area and advise on the remedial measures to mitigate landslide problem in the area. The investigators were directed by the Director, WIHG to carry out the field investigations and to prepare the landslide hazard zonation map of the Dharamsala town and adjoining area.

The Dharamsala town and adjoining area was inspected by the investigators four times during the tenure of the project. The area was investigated for the preparation of landslide inventory, geology, landuse, landcover, slope, drainage and population maps. In addition to the work assigned, the elements at risk due to these landslide hazards were also taken into consideration for the preparation of landslide Risk Assessment map of the town and the adjoining areas. Besides this, some of the active slide zones have also been monitored to have a rough idea of the rate of movement of these slides. During the course of these investigations, the investigators had close interaction with the Deputy Commissioner, Dharamsala and other officers of state departments i.e. PWD, Forest deptt. and Town & Country Planning. These interactions were very useful and provided important inputs for the preparation of this report.

INTRODUCTION

Although, a lot of literature that provides an overview of the landslides in the Himalaya, especially in Himachal and U.P. Himalaya is available. yet none of these studies give detailed information on the landslide problems which individual hill towns are experiencing. The landslide problems of individual town have not been completely understood, compared and analyzed by researchers to help the planners, engineers, decision makers. and insurance agencies at the state, district or panchayat level in estimating the potential landslide hazards and risk in the towns and to take appropriate mitigation measures. Moreover, there are no regulations to effectively reduce landslide hazards and losses. Himachal Pradesh is one of the states, which

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always remains in the grip of landslides, mostly during rainy seasons. These landslides have damaged or destroyed roads, railway lines, pipe lines, electrical and telephone transmission lines, houses and commercial buildings, irrigation canals, sewers, bridges, helipads, forests, fisheries, parks, recreation spots and farms etc. A great extent of landslide damage goes undocumented because it is considered along with its triggering events and thus, included in the reports of floods, earthquakes, cloudbursts etc., even though damage from landsliding may exceed all other costs. So, there is a need to collect information and data on the potential landslide damages separately and use it for landslide hazard mitigation effectively.

Dharamsala town and adjoining area has been found to be under severe landslide problems, as indicated by landslide damages to roads, pipe lines, transmission lines, forests, agricultural fields and buildings of Tikka Gamru, Mcleodganj, Totarani and on the Mcleodganj – Dharamsala road. The landslide problems in the inhabited areas of Dharamsala town and adjoining area have increased during the last two decades, following unplanned development and urbanization. This activity has led to increase in uncontrolled discharge of sewerage and household effluents, which has further added to deterioration. The rapid urbanization has also disturbed the natural drainage system, having created temporary or stagnant water pools due to choking of channels by garbage. This has augmented seepage of water in the unconsolidated debris along steep slopes.

This report provides the details of active slide zones and suggests mitigation measures to control them. A landslide hazard zonation map depicting different zones of relative instabilities in the Dharamsala town and adjoining area has also been prepared. In addition to this the report has considered the elements at risk for the preparation of landslide risk assessment map of the study area. Besides this, some selected slide zones have also been monitored for relative movements with the help of measuring tape using trigonometric method to have a first hand idea of the extent of potential movement in the area.

LANDSLIDES IN DHARAMSALA TOWN & ADJOINING AREA

The town of Dharamsala and its suburbs in the Kangra valley provide a type example where unplanned development and urbanization have added to hazards from landslides. The town is situated on the southern slopes of Dhauladhar Ranges and has expanded manifold during the last two decades. It has experienced many damaging landslides, which have destroyed the roads,

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houses and communication network. The Dharamsala area has a history of instability associated with heavy rainfall and glaciated overstepped valley sides which are incised into sandstone and claystones of Dharamsala Group (=Dagshai-Kasauli). This report describes the various active landslides studied in the area. Some of these landslides were reactivated in 1997, 1998 and 1999. These landslide zones currently occupy an area of about 1.6 sq.km. of the town (including inhabited areas and roads) and have been studied in order to understand the basic factors responsible for ground movements which may be useful in mitigating landslide hazards in this area.

The area is seismo-tectonically very active being in the epicentral zone of 1905 Kangra (M> 8) earthquake (Fig.1). A number of damaging earthquakes also rocked the area during the last three decades repeatedly, and thus, have influenced the shear strength of rocks and soils. The slopes are steep and the area has one of the highest relief (> 4000m) in the Himalaya. The Main Boundary Thrust and the Main Central Thrust (= Chail Thrust) lie very close to each other and run along the northern fringes of the Kangra valley (Fig.2). The slopes north of Dharamsala have undergone rapid urbanization, particularly, during the last two decades or so. Extensive deforestation to accommodate residential, tourist and commercial establishments has laid bare sensitive hill slopes which often fail during the monsoon and winter rains. A number of roads have suffered damage due to heavy traffic load, bad alignment and improper management of drainage. Choking of natural drainage by plastic or polythene bags has created water pools, which leads to seepage and slow creep of unconsolidated debris along steep slopes. Uncontrolled discharge of sewerage and household effluents on the surface has further added to deterioration. Many houses have been damaged or are likely to experience damage in the near future. The problem is deteriorating everyday and many areas like Tikka Gamru, Totarani, Eastern slopes of Mcleodganj, and Dharamsala-Mcleodganj road at a number of points starting from Municipal area has become vulnerable and disaster prone. Some of the residential areas have become inhabitable due to frequent & sudden movements in the groundmass.

GEOLOGY AND GEOMORPHOLOGY

Geologically, the Dharamsala town is situated on the rocks of Dharamsala Group (=Dagshai -Kasauli Group) which consist of sandstone with alternating bands of clays, shale and siltstones. The rock formations are highly jointed with an average fracture density of 0.07 cm/cm^2. The southern part of the Dhauladhar ranges are covered by Tertiary sediments and thick

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regolith of quaternary period consisting of angular boulders set in rocky debris or soil and the northern part is covered by limestone, phyllites and slates of Pre-Tertiary period. The major part of the Dharamsala Town area and Mcleodganj hill slopes are covered with overburden material of glacial and debris deposits and consists of clay with small rock fragments of silt stone. The geological map prepared on 1:15000 scale revealed that Dharamsala Town is sandwiched between two major NW-SE trending tectonic thrusts i.e. Drini Thrust to the south of Dharamsala town (passes from Garoh Khas-Sukoh to the east) and Main Boundary Thrust (MBT) passes just north of Naddi (Fig.2). These two tectonic plane are very active and the 1986 Dharamsala earthquake was triggered due to tectonic activity along the Drini Thrust (Kumar and Mahajan, 1991) which caused much damage to Naddi, Mcleodganj, Nargota Chilgari, Tikka Gamru, Ram Nagar and Shyam Nagar localities. So due to the presence of these two thrusts dipping northeast, the rock formation remain under stress, which got released in the form of movement along fractures and faults.

Geomorphologically, the Dharamsala town is situated on the NE-SW trending spur abutting against the southern slopes of the rising Dhauladhar ranges and exhibits a rugged topography, steep slopes dissected by numerous drainage channels. The relief in the area varies from 800 m a.m.s.l. in the south to >4000 m a.m.s.l. in the north. The mean elevation varies from 1300 m at Kotwali Bazar to 1700m at Totarani. The highest elevations in inhabited areas are around Mcleodganj(1900m). The hill slopes consist of sandstones and clay covered with slided debris and glacial deposits of Quaternary period which was displaced from the northern slopes in the terrain. The area is drained by N-S and NE-SW trending streams, which flow in the south and southwestern direction. The important perennial channels are Churan Khad in the east and Banoi Khad in the west. Both these channels are fed by water from snow covered high ranges of Dhauladhar mountains. The drainage density in the area under investigation ranges from 1.0 in the southeastern part to 7.9 in the northern part, with an average of 4, which indicates greater degree of dissection by natural drains.

It has been observed that out of the study area about 25% of the area is covered with dense forests in this region whereas 25% is covered by agricultural land and population inhabits 25% of the total area. The rest of the area is barren in nature.

The field observation in the study area revealed the presence of numerous scars, cracks, slumps, tilting of trees and structures, distressed buildings and retaining walls which depict past and present landslide activity in this region.

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SLOPE MORPHOMETRY

Since the slope plays a major role in destabilizing the terrain besides other geo-environmental factors. Therefore, slope analysis is one of the factors used in hazard assessment. Slope morphometry map prepared on 1:15000 scale (Fig. 3) classified the terrain into five slope categories i.e. very gentle (≤15^0), gentle (16°-25^0), moderately steep slope (26°-35^0), steep slopes (36°-45°) and escarpment/cliff (≥45^0). The slope morphometry map has been prepared on the basis of topographical map using grid method. A grid size of 150*150 sq. mt. was used to find slopes with uniform inclination within which the contour lines have the same standard and direction. The slope morphometry map indicates that in general the slopes in the upper part of the Dharamsala region are moderate to steep, whereas the slopes in the northern part have steeper gradient. The steepness of slopes makes the terrain susceptible to erosion.

The relief map on 1:15000 scale (Fig. 4) of the region indicates that lowest relief is 1100 mt in southern and southwestern part of the area under investigation and highest relief of 2400 mt in the northeastern part of the study area. There are two major ridges running NNE-SSW direction and serving as a drainage divide between the Churan Khad and Banoi Khad. These major ridges also accommodate the population of the area and have lot of problems related to landslide.

HYDROLOGICAL EFFECTS

Water is the main factor in destabilizing hill slopes. Identification of water source, water movement, amount of water and water pressure are, as important as the identification of the material constituting the slopes. In an area with highly jointed rocks and the presence of thick over burden, the surface and ground water play a crucial role in the evolution of landslides. The rainfall has been found as the main triggering factor for causing major slide in Dharamsala Town and adjoining areas.

The Dharamsala town receives maximum annual rainfall (260cm/yr) in the state. Most of which is confined between period from July to September. The fig. 5 shows the histogram of average monthly rainfall of the Dharamsala township. During 1997, a number of slide zones have been reactivated due to heavy rain fall, although in every rainy season the roads in Dharamsala-Mcleodganj tract have been subjected to subsidence and slide movement. These landslides have damaged or destroyed roads, water pipe lines, electrical and telephone transmission lines, houses

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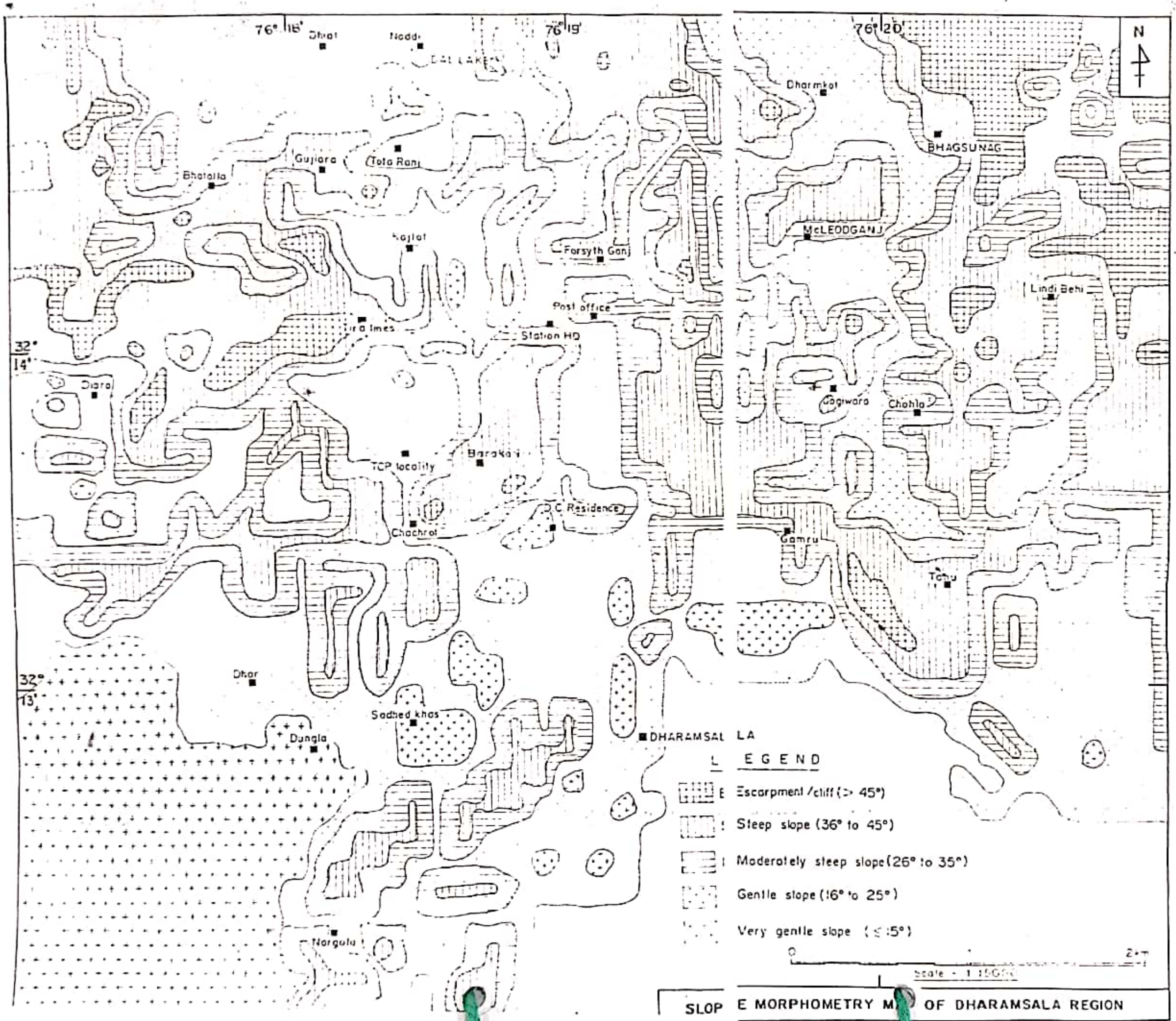

SLOPE MORPHOMETRY MAP OF DHARAMSALA REGION

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and commercial buildings, irrigation canals, bridges, forests, parks, recreation spots and farms etc. A great extent of landslide damage goes undocumented because it is considered along with its triggering events i.e. rain fall, although these landslides may exceed all other costs. However the present study has focussed the attention to all other causative factors which are leading to the landslide movement in the area. No doubt heavy rainfall during monsoon season helps in triggering the event.

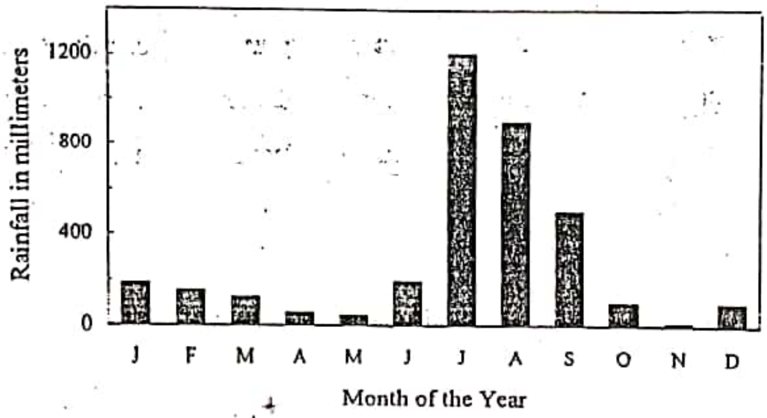

Fig. 5: Normal Monthly Rainfall in Dharamsala Region

Besides rainfall, the injection of septic wastewater and other household disposal directly into the subsurface can also lead to slope failure. The Dharamsala area as mentioned is made up of sandstone with inter bedded clay and clay stones. The clay stones form the slip surface and most of the slope failures occur along the dip direction or in the direction of joints. So whatever water comes from septic discharge on the over burden material, it starts flowing along the slip surface in the slope direction and this leads to sliding.

The septic wastewater, leaky water pipes and improper drainage devices add to ground water recharge. The subsurface disposal of septic and household effluents is generally the most significant ground water contribution by local residents. The mismanagement of daily wastewater of bath and kitchens also adds to the system. Leaky pipes and cracked drainage devices are generally the aftereffects of landslide movement, and serve to aggravate an existing problem. The increased urbanization with the introduction of impermeable cover in the form of roofs and paved roadways covers the permeable hill slopes. So the runoff volume increases. The increased runoff contributes to mud flows, flooding and the further saturation of existing and potential landslides

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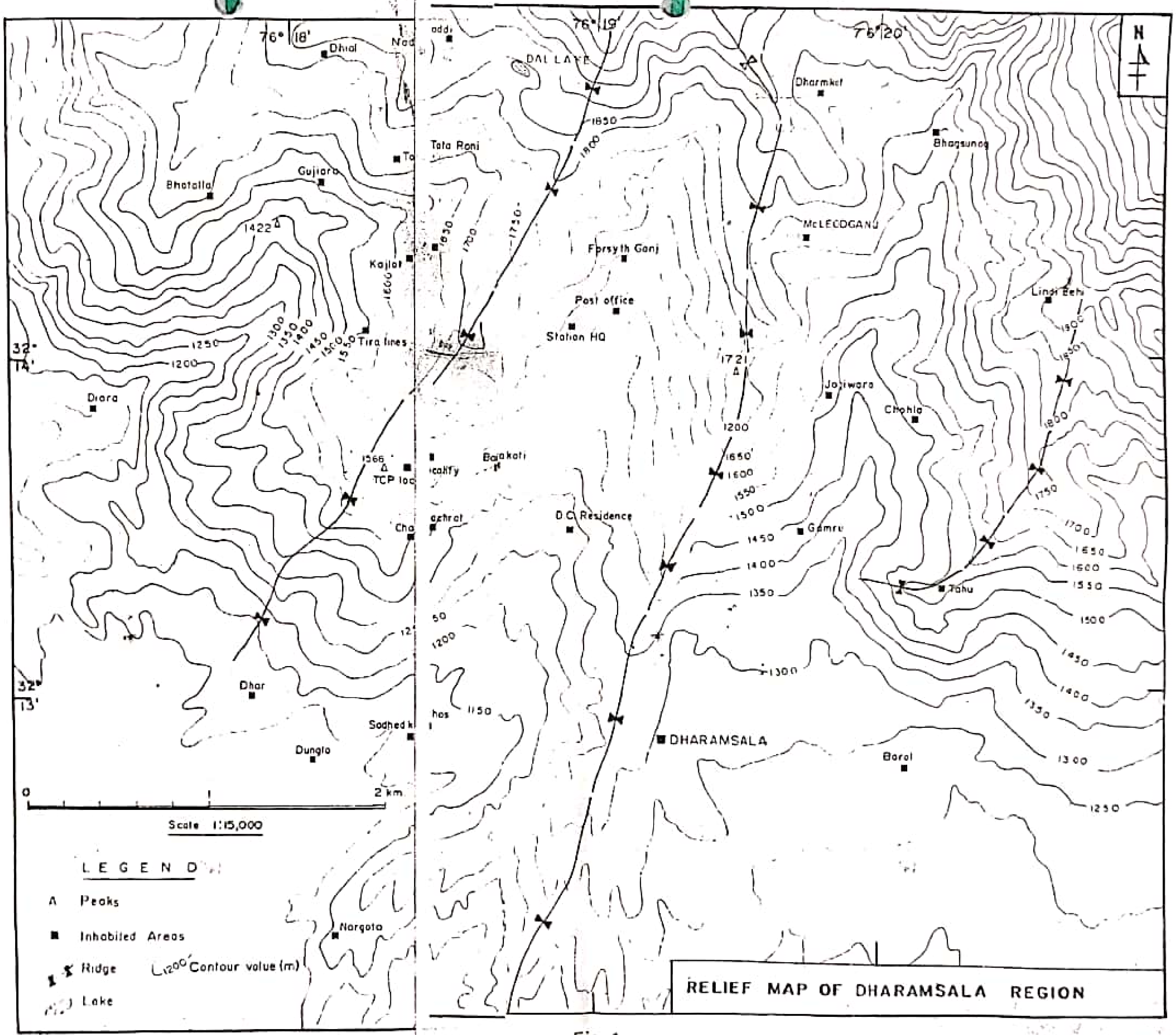

RELIEF MAP OF DHARAMSALA REGION

Fig. 4

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masses. The landslide area of Tikka Gamru, Gujiara, Jogiwara, and Station HQ zone are the main sites affected due to septic water and waste water disposal apart from precipitation.

A simple calculation of infiltration from rainfall, and from septic tank has been done to distinguish the contributing agents. Although it is well known that the Dharamsala town is situated at a high gradient from 1300m to 2000m in which the infiltration will be very less, and the runoff will be higher. If we compare the sewerage discharge from a typical Indian house hold (six persons) with the water that fall as rainfall on a bare 0.25 hectare plot of land and successfully migrates into the ground water supply, we get the following results:

Septic discharge = (6 persons) x (150.0 liters /person/day) x 365.25 days/yr.)

= 328752 liters/yr.

Infiltration from rain fall

= 2.6m/yr x 4047m^2/acre x 0.25 acre x (1000/ms) x 0.05

= 131527 litres/yr.

=131527 litres/yr. in 0.25 acre plot (bare land)

So if we consider the rainfall as 260 cm/yr. then the septic discharge infiltration is around three to four times higher than the infiltration of rain water but if we take the hill slopes of Dharamsala Town into consideration where surface runoff is very high because of slope and urbanization then the contribution from septic system to ground exceeds far that of the rainfall. According to the 1991 census the population within Dharamsala municipal limit is only 17493. If we also count the floating population of the area, the population in the Tibetan establishment (main agent for Jogiwara landslide and Tikka Gamru landslide) and Army Cantonment population (main agents for station HQ landslide zone and Kajlot landslide zone and some other slide zones). then one can imagine the amount of water being infiltered into the subsoil of Dharmsala town and its surrounding. This is a very conservative estimate, because all of the septic water goes directly into the subsurface, whereas about 2/3 of the rainwater leaves the system via evapo-transpiration and runoff. The presence of septic tank system in Dharamsala

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town, Mcleodganj and Army |Cantt. area can be disastrous so, it is essential to have a proper **sewerage system to mitigate landslide hazards in the town and surrounding areas.**

DRAINAGE ANALYSIS

A drainage map (Fig. 6) of the Dharamsala town and adjoining area has been prepared on 1:15000 scale with the help of toposheet and field observations. Three major streams namely Churan Khad (CK), Banoi Khad(BK) and Gaj Khad flow through this area. The drainage analysis of different basins of Churan Khad (CK); Banoi Khad (BK); and Gaj Khad has also been carried out . Each basin has been subdivided into different sub-basins as (A,B,C,D) of third order to find out the drainage density and its effect on the mass movement of Dharamsala township and adjoining area. Further, a physiographic analysis of the drainage basins in the study area (Table-1) indicates that although the terrain is highly dissected by numerous drains (with drainage density of upto ~8) yet the basin slopes of these drainages are not very steep. In fact, they have generally gentle to moderate slopes. Hence, the effect of water flow in these drains is higher seepage of water in the ground rather than greater erosion of the surface stratas. This results in deep-seated failures of these slopes which is aggravated further by seepage from the waste water and septic tanks discharges, as discussed above. Thus, there is an urgent need to check such inflows of water into the slopes to prevent or control any failure and mitigate hazards in the area.

LANDUSE AND SOIL COVER(OVERBURDEN MATERIAL)

The nature of landuse and overburden material is an indirect indication of the stability of hill slopes. The forest cover in general reduces the action of climatic agents on the slope and protect them from the effect of weathering and erosion. On the other hand, young loose material (Debris) soil cover have low shearing resistance and erosion resistance. The barren land shows faster erosion and greater instability, whereas, the populated land adds to high seepage and human interference, thus, leads to greater instability to slopes. The agriculture is generally practiced at low angle and gentle slope as such considered to be stable. Demographically, the Dharamsala township has thirteen municipal wards and holding a population of 17493 as per 1991 census. It is one of the fastest growing towns especially , the development is at a high rate along the Khara Danda road between Mcleodganj and Dharamsala and in the Cantt. area. The major landuse patterns of the area as shown in Fig. 7 reveals that a cultivated area accounts for only 25% of the land, 25% area is under forest cover and 25% area comes under populated area

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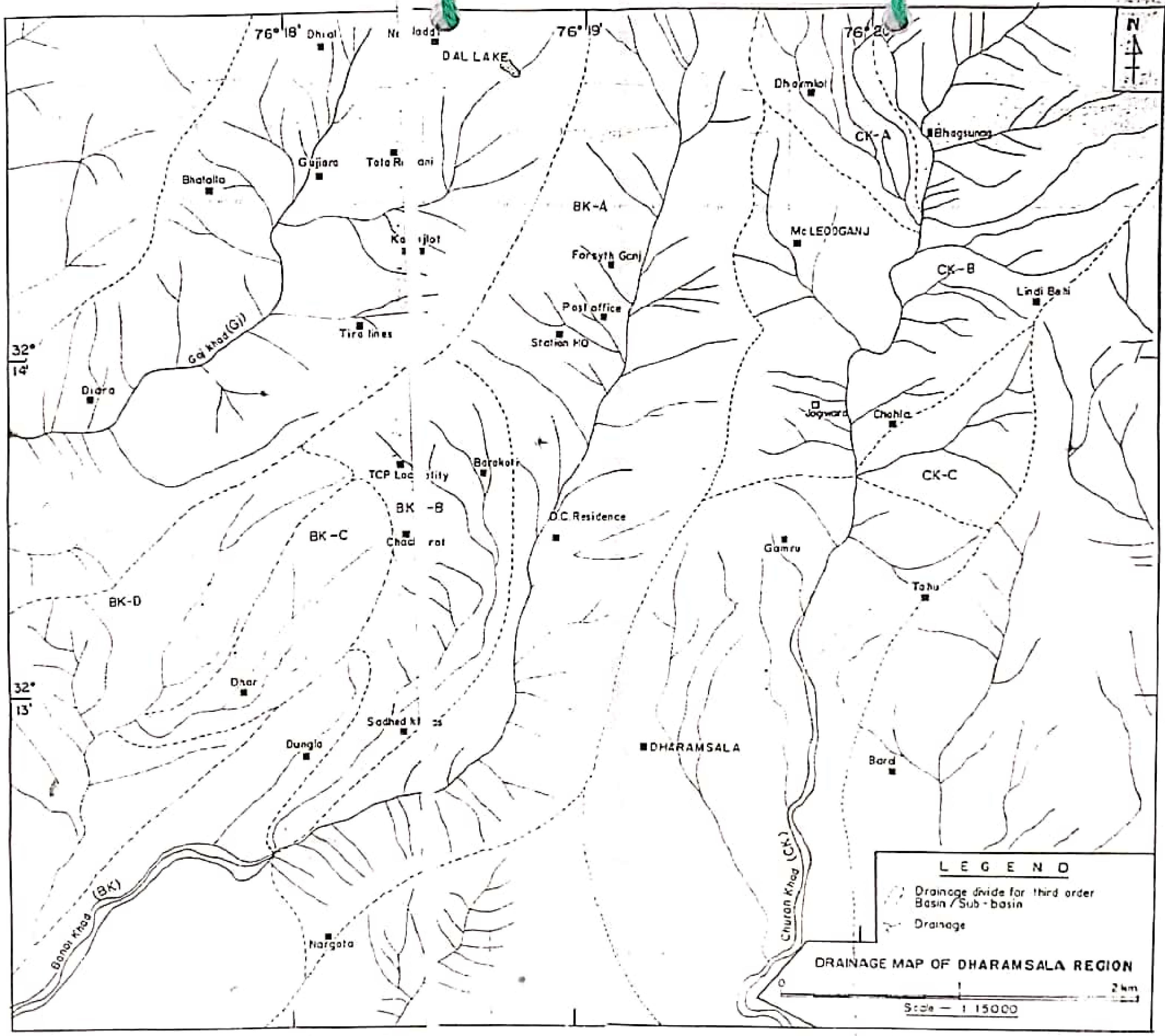

Fig. 6

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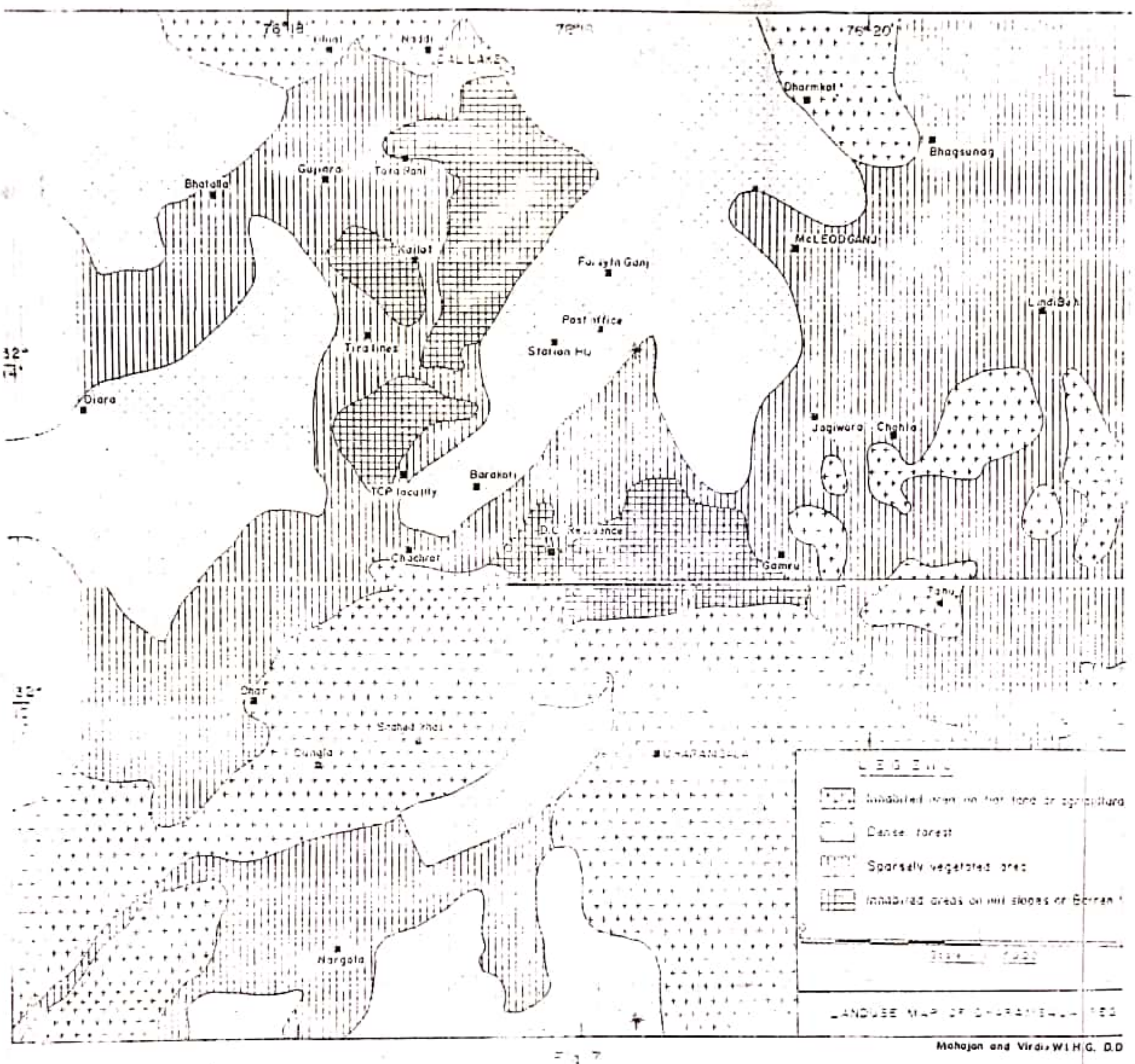

Fig 7

Mahajan and Virdi, W.I.H.G. D.D

Table1 : Physiographic Characteristics of Third Order Drainage Basins / Sub-basins in Dharamsala Area

Basin Ref.	Sub-basin	Basin Area (Km^2)	Basin Length (Km.)	Basin Width (Km.)	Length of streams (Km.)				Number of streams				Mean Length of streams (Kms.)				Drainage Density	Basin Relief (m)	Basin Slope
					L_1	L_2	L_3	L	N_1	N_2	N_3	N	$\bar{L}_1$	$\bar{L}_2$	$\bar{L}_3$	$\bar{L}$			
Churan Khad	Ck-A	0.63675	1.59	0.53	2.81	2.06	0.15	5.02	8	2	1	11	0.35	1.03	0.15	0.46	7.88	265	9°
	Ck-B	3.9375	2.65	1.81	14.39	3.71	2.42	20.52	40	5	1	46	0.35	0.74	2.42	0.45	5.2	1005	21°
	Ck-C	0.567	1.28	0.75	1.59	0.68	0.83	3.10	5	2	1	8	0.31	0.34	0.83	0.39	5.4	460	20°
Banoi Khad	Bk-A	6.83325	5.30	1.59	22.57	3.00	4.92	30.49	50	9	1	60	0.45	0.33	4.92	0.51	4.46	920	10°
	Bk-B	1.6425	2.72	0.68	3.33	1.8	1.10	6.23	9	4	1	14	0.37	0.45	1.10	0.44	3.79	520	11°
	Bk-C	0.8325	1.81	0.56	1.43	1.21	0.75	3.39	4	2	1	7	0.35	0.60	0.75	0.48	4.01	535	16°
	Bk-D	2.24325	3.48	1.13	5.45	1.59	1.54	8.58	14	2	1	17	0.38	0.79	1.54	0.51	3.82	410	7°
Gaj Khad	Gj	5.589	3.93	1.80	15.37	4.5	2.55	22.42	40	8	1	49	0.38	0.56	2.5	0.46	4.00	111	16°

Abbreviations: L_1- Length of 1st order streams, L_2 - Length of 2nd order streams, L_3- Length of 3rd order stream, L- Total Length of streams, N_1- Number of 1st order streams, N_2- Length of 2nd order streams, N_3- Number of 3rd streams, N - Total Number of streams in a 3rd order basin/sub-basin, $\bar{L}_1$- Mean length of 1st order streams, $\bar{L}_2$- Mean length of 2nd order streams, $\bar{L}_3$ - Mean length of 3rd order streams, $\bar{L}$ - Total Mean Length of streams in 3rd order basin/sub-basin

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as per 1968 survey of India Toposheet, However the forest area and cultivated land has been degraded and about 20% of the forest land and about 33% of the cultivated land has been converted into a inhabited land since 1968. The increasing urbanization and deforestation on the hill slopes has brought in manifold problems to the Dharamsala Township one of which is landslide activity besides increase in earthquake risk and environmental degradation.

Similarly, a soil cover (overburden material) map of the area under investigations has been prepared from field studies on 1:15000 scale (Fig. 8). The map indicates that most of the northern hill slopes in this area are covered with debris(young loose material) consisting mainly of clay with fragments of sandstone. A part of the southern portion is covered with older well-compacted alluvial fill along a ridge running from Kotwali Bazar to Dharamsala college, which is relatively safe from landslide problem. Rest of the southern slopes are covered with clayey soil resting on mostly a gentle and very gentle slopes underlain by weathered granitic rocks.

SITE INVESTIGATIONS

Although the general appearance of the terrain and vegetation cover allows us to interpret that Dharamsala town has long a history of slide movements, but the load of urbanization on the hill slopes and specially in localities like Mcleodganj, Forsythganj, Cantt area, Khara Danda road, Kajlot, Gamru, Gujiara etc and seepage along Dal Lake has induced major problems to the stability of the area. Detailed investigations of each and every slide, indicate that most of the active landslides today developed due to sewerage disposal in the area. Although the area receives high rain fall but the infiltration rate of sewerage disposal exceeds 7-8 times higher than the rain fall infiltration in most of the slide zones where community plays a big role. Besides the inhabited areas, the sewerage disposal is also causing great problem to the Dharamsala-Mcleodganj road which is facing number of slides like D.C Residence road slide, parapet 164/3 slide zone, Forsythganj, Post office slide zone and Station head quarter Cantt. area slide zone etc.

The most common slide movements in the Dharamsala mountainous area are transnational and rotational. Each individual landslide is distinguished by simultaneous creep and sliding flow resulting in specific failure and high rate of displacement. All the slopes of the Mcleodganj-Dharamsala roadsides are affected by landslide. Most of the failures are concentrated along the natural and artificial drainages. where relatively steep banks are eroded laterally.

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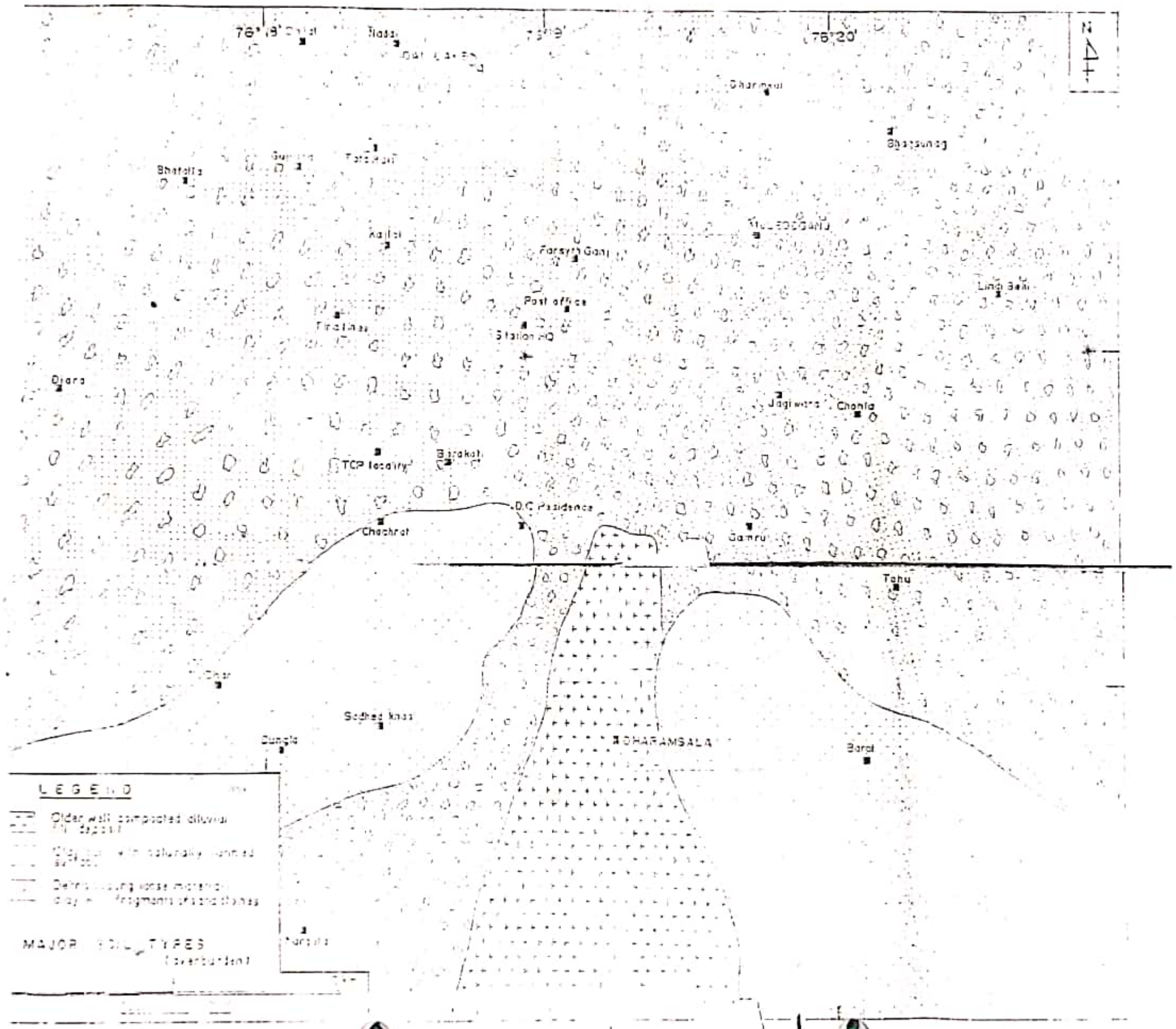

76°18'
76°19'
76°20'
N
Naddi
Dal Lake
Dharmkot
Bhagsunag
Bhatolia
Tota Rani
Kajlot
Forsyth Ganj
McLEODGANJ
Lingi Bani
Post office
Firatnas
Station HQ
Jogiwara
Chanla
Barakot
TCP locality
D.C Residence
Chachrot
Gamru
Tahu
Sadhed khas
Dungla
DHARAMSALA
Barol
LEGEND
Older well compacted alluvial fill deposit
MAJOR SOIL TYPES
(overburden)

adjoining areas, a landslide inventory map (Fig. 9) has been prepared on 1:15000 scale on the basis of field investigation. The details of each slide zone have been given in Table-2. Some selected slide zones, considered important from socio-ecological and techno-economical point of view, have been discussed herewith in greater detail.

After a careful study of all the failed slopes in the area, it was also decided to monitor and estimate the extent of movement at some selected sites so that appropriate remedial measures may be suggested at proper locations to mitigate landslide hazards. Monitoring of landslide movement has also been undertaken using trigonometric method, although this gives a rough estimate but it gives a relative rate of movement among various benchmarks in different slide zones. A number of benchmarks were fixed on slopes covering different parts of the slide zone following a systematic plan. These markers were monitored periodically with the help of a measuring tape and the relative displacement were determined. It has been observed that downhill movement varying from few mm/cm has occurred over a period of six months. Further work is in progress.

DESCRIPTION OF LANDSLIDE ZONES

Tikka Gamru Site

The site is located in the Tikka Gamru locality of Dharamsala Town. The slide affected area lies at the southern hill slope of Central Administrative Tibetan complex (CATC) and east of Mcleodganj - Khara-Danda road. The area is bounded by $32^0 13'$-$32^0 14.5'$ N and 76^0 $19'$-76^0 $20'$E. This slide was triggered in the year 1995. It is an active rotational slide and covers an area of about 0.1755 sq. km. The length of the affected area is approx. 500 meters i.e. from crown to the toe and width of more than 50 meters at the toe. The failure plane is along the SSE direction (N170^0). The slopes have moderate to steep gradient (30^0-40^0) and consist of clay, sandstones and slided debris. The slopes are generally wet due to percolation of water from higher part. The debris has been derived from the weathering of old landslide rocks. The area has relative relief of 200 mts. from 1300 meters on the Dharamsala Khanyara road to 1500 meters in the north. The upper hillslope are 30°-35° in slope and formed by the weathering of Tertiary rocks of Dharamsala Group. The lower slopes are mainly form part of piedmont fan with slope varies from 20° to 4°. The fan section consists of large boulders derived from Tertiary and Pre Tertiary

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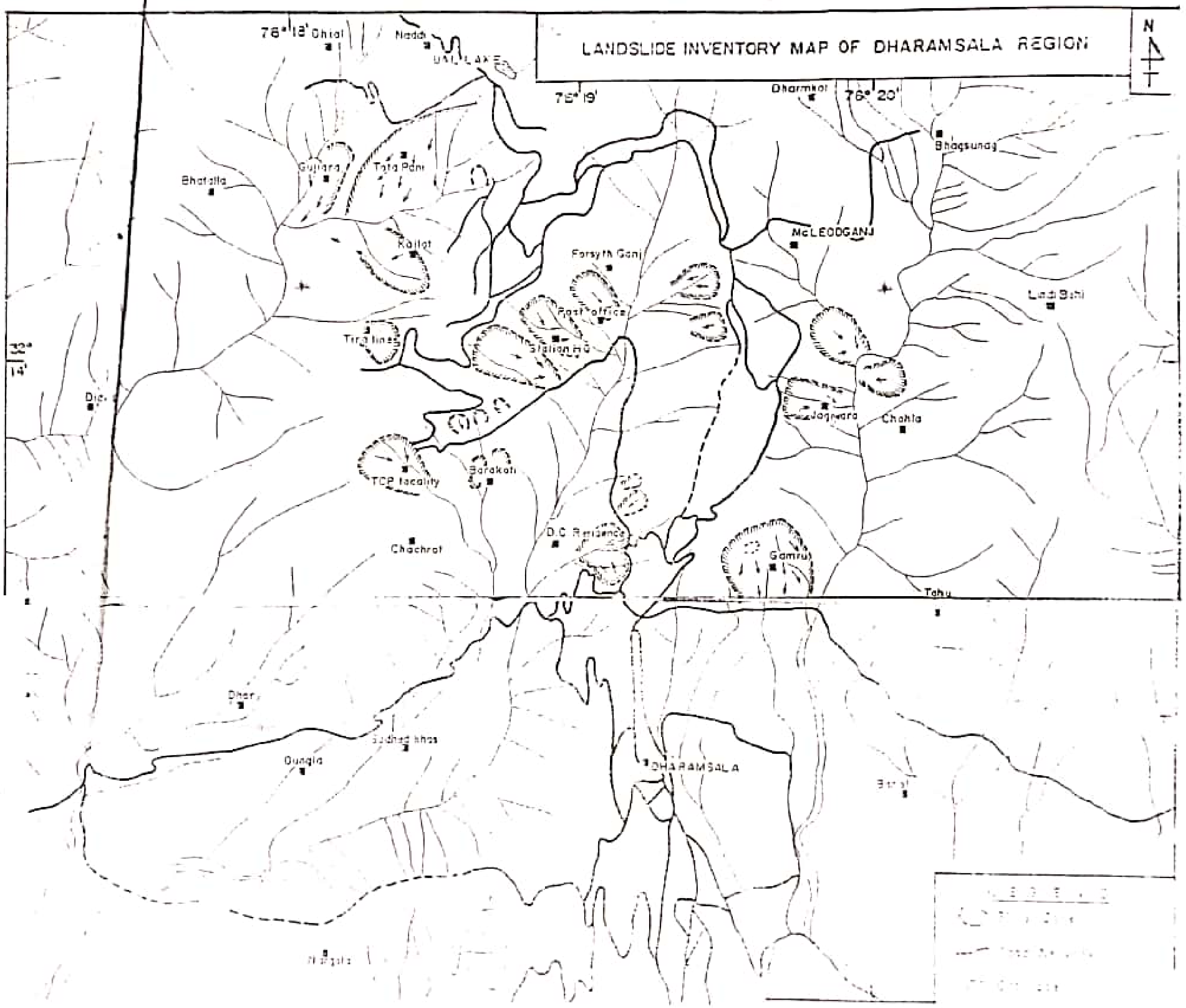

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cks and generally buried under hill slope scree. The scree at the top is covered by a 1-1.5 m thick layer of soil. The slopes have residential building over them. It has been observed in the field that there is very high seepage of wastewater from the Central Administrative Tibetan Complex(CATC), thus creation of swamp in the crown of the slide. Seepage from leaky water pipes and natural drains; chocking of natural drains, hummocky topography and presence of numerous minor scars, cracks, slumps and convex slopes segment in the upper fan section and hill slope scree indicates that the area was also affected by landslide activity in the past(Fig. 10). Some transverse E-W trending cracks are also evident from the surface observations at the slide zone (Fig.11). A displacement in the boundary wall constructed in the area (Fig.12) indicates that it is an active slide zone. Bulging of breast wall and shift of 5-7 cm has also been noticed in the walls of the house of Mrs. Bina Devi. Although Prof. Tandon's house in this locality does not show any sign of failure at present yet the houses located adjacent to his house are found distressed due to slope movement in this zone (Fig.13). The reason for Prof. Tandon's house not showing any failure signs could be the position of swamp area which is located at a relatively lower elevation. Thus, there is no problem of seepage.

The process of mass movement in this section is still continuing as indicated by numerous terraces formed by the creep movement, creation of space between embedded boulders and land. High rate of seepage along the upper slopes and high porosity of surface scree further facilitates the creep movement in the area.

The monitoring of slope movements has been done using 13 benchmarks fixed in the body of the slide zone with the help of a measuring tape. The relative rates of movement in different parts of the slide were assessed using trigonometric survey method. It was found that the extent of movement varied from 5mm to 30 mm. An attempt was also made to monitor the propagation of cracks developed in the ground and in the residential buildings within the slide zone.

The main causative factors for the slide are seepage, septic tank and wastewater disposal from Central Tibetan Administrative Complex as well as inhabitants of Gamru area and uphill slope residential areas. Although this is a very old slide but has been reactivated after a long time due to heavy seepage from the residences uphill in the clay soil, most of the residential buildings on the upslope or downslope are constructed on debris material which consist of dominantly clay with some boulders of sandstone embedded in it. The clay normally absorbs water and thus leads

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TABLE 2: INVENTORY OF LANDSLIDES IN AND AROUND DHARAMSALA TOWN, DISTRICT KANGRA (H.P.)

S.N.	Location	Type of Landslides & Movement	Geomorphic position and slope	Lithology and Material involved	Failure plane	Active/ dormant	Joint pattern	Land use	Hydrological conditions	Major causes	Remarks
1	Near Kand Tea Garden	Debris slide with rotational slip	Steep slope	Clay with small rock fragments of sandstone with 4-8m overburden	NW-SE Along contour slope	Active	----	Tea garden and forest	No seepage failure only due to heavy rain fall	Steep slope, heavy rain fall in 97-98 and toe cutting	The slide first occurred in 1997 during rainy season which subsides the overburden material to 20ft. Further subsidence took place after 1998 rainy season. This has reduced the boundary of Tea garden, uprooted big and small trees, thus posed great risk for environmental degradation and to tea garden
2	Kand Village on Khanyara road	Debris slide with rotational slip	Moderate steep slope	Dominating clay with small fragments of sandstones as overburden material No rock exposed	SW-NE with SSE direction of movement i.e. contour converging slope	Active	---	Barren land occupied by residential buildings	Semi dry in normal conditions	Slope, road cutting, rain fall and toe cutting	Rotational slip with subsidence of 3-4 ft The house located at the SSE slope of the slided mass showed subsidence in one attached wall from 6inch to 1ft in one year.
3	Near Manjhi Khad	Debris slide with Translational slip	High slope almost vertical escarpment	Clay with fragments of sandstone	Vertical slope failure	Active	----	Barren Land	Semi Wet land	Toe cutting, Slope, Shear zone at toe of the slide	Slide has triggered due to heavy rain fall.
4	Same locality but on the west of site no 3 and west of natural drainage	Debris slide with subsidence and rotational slip	Lower slope 38° towards SE at the top and steep slope in the mid and toe of the slide	Clay with fragments of sandstone	SW-NE	Active		Barren Land	Slumpy in the middle of the slided mass and dry on the scarp. Largely wet	Toe cutting, Slope, High water seepage from NW direction uphill.	If this slide is not controlled by first plugging the seepage then due to toe cutting during rainy season by the nala the crown of the slide may go upto the tea garden situated uphill and can also affect the inhabitants staying uphill
5	Tika Gamru Landslide	Debris slide with rotational slip	moderate to steep slope	Clay with fragments of sandstone	SE	Active		Residential	Very high seepage of waste water from the Tibetan complex, thus, creation of swamp at the crown of slide, seepage from lenky water pipes and natural drains; chocking of natural drains. Generally wet	Seepage, septic tank disposal of Tibetan complexes well as inhabitants of Gamru areas and waste water disposal of uphill slope residential areas	This is an very old slide which has been reactivated due to heavy seepage from uphill and by the inhabitants of the area in the clay soil. Thus leads to solifluction and creep movement in the area. Some of the recent construction and old constructions shows clear evidences of its movements. There is an urgent need to drain all natural drains; control septic tank disposal and chanellise waste water disposal of the Tibetan complex and resident of Gamru, not only to save Gamru area but also Ram Nagar and Shyam Nagar.

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S.N.	Location	Type of Landslides & Movement	Geomorphic position and slope	Lithology and Material involved	Failure plane	Active/ dormant	Joint pattern	Land use	Hydrological conditions	Major causes	Remarks
6	M.P. residence slide	Debris slide with rotational slip	Moderate slope 30-350	Clay with small rock fragments of sandstone. Clay is the maximum litho unit	SW	Active	----	Residential and Agricultural	Very high seepage. Wet condition	Seepage, heavy rain fall in 97-98, slope gradient	Seems to be an old slide reactivated due to heavy rains during 1996-97 but the main agent responsible for the slide is the seepage from uphill. Development of surface cracks at number of places in the open field of residence show high extent of movement which may leads to further seepage during rainy seasons and damage the inhabitants down hill. Already one house had been damaged thrice from 1984 and was advised not to construct house there again.
7	Road slide below D.C. Residence/ Municipal park slide zone	Debris slide with rotational, translational slip and bouncing effect	Very steep slope	Clay with rock fragments of sandstone	SSW	Active	---	Upslope road and residential and down slope forest	Semi wet	Seepage from the drainage, toe cutting, steep slope along the cliff, toppling	Very old slide since 1960, which was retained after careful study of geologist in 1968. Again reactivate in 1997 and subsided 3-4 meter deep with bouncing of land mass in the mid of the slide zone. The development of surface cracks and loading at the surface makes the slide more vulnerable to mass movement.
8	Hotel Akriti slide zone	Debris slide with rotational and translational slip	Steep slope (40°)	Clay with fragments of sandstone	SW	Active	----	Upslope forest and down slope buildings, road and agriculture	Dry slope	Heavy rainfall	Needs afforestation of fast growing plants or bushes
9	163/3 Barakoti road slide zone	Debris slide along the joint planes with rotational slip	Moderate slope	Clay with fragments of sandstone and sandstone rock of Dharamsala are exposed along with slip surface of clay	N 130°	Active	N 220°/ 50°	Upslope forest middle Barren and lower portion covered by road	Dry slope but seepage from upslope	Underground seepage, heavy rainfall, slope and high density joints	Needs afforestation in the area and control of seepage
10	In between parapet 163/3- 163/4 slide zone	Debris slide along the joint planes with rotational slip	moderate slope	Clay with fragments of sandstone and sandstone rock of Dharamsala are exposed along with slip surface of clay	N 140°	Active	--	Upslope forest middle Barren and lower portion covered by road	Dry slopes	slope, joints and heavy rain fall	Development of transverse and radial crack are noticed showing activity along the joints. Uprooting of plants is also seen. Surface cracks transverse to the slide direction

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S.N.	Location	Type of Landslides & Movement	Geomorphic position and slope	Lithology and Material involved	Failure plane	Active/ dormant	Joint pattern	Land use	Hydrological conditions	Major causes	Remarks
11	Parapet 163/4 Landslide zone	Debris slide along the joint plane with rotational slip	Moderate slope	Clay with small rock fragments of sandstone.	SSW	Active	-	Forest	Dry slope but seepage from upslope	Seepage, heavy rain fall in 97-98 and slope	Development of transverse and radial crack are noticed showing activity along the joints. Uprooting of plants is also seen. Surface cracks transverse to the slide direction
12	TCP locality slide zone	Rotationl with debris flow	Moderate slope	Red shale and highly shattered grey shale is exposed below the overburden	Dip direction of the rocks i.e. NE	Active	N180°/ 40°	Scattered forest	Wet	Slope and toe cutting	Highly shattered rocks and dip slopes undergoing toe cutting leads to active sliding.
13	TCP Locality Bridge slide zone	Translational	Cliff i.e vertical	Red shale and highly shattered grey shale is exposed below the overburden	Dip direction of the rocks i.e. NE	Active	135°/ vertical on SSW side---	Road at the crown	Normally dry slope but become more wet during rainy season	Heavy rainfall, slope, joints pattern, high density of joints	Needs retaining and anchoring, grouting of the rocks in order to save road, although the road is towards dip direction but fractur density of rock may leads to failure
14	Tira lines Landslide zone	Translational on the road slide and rotational on the opposite side	Vertical to 60° slope on cliff side and 22° on the other side	Grey shale and sandstone	SSW and NNE	Active	N 135°/ vertical on SSW side and 330°/ 62° Highly jointed	Forest on one side with residential and road on the crown of the slide	The NW face generally Wet condition one due to seepage from the residential and cantonement area of Tira line and from the natural drain. The NE face remains dry	Toe cutting, high cliff, high density of joints, high seepage underground	Needs retaining and anchoring grouting of the rocks in order to save road, although the road is towards dip direction but fracture density of rock may lead to failure on northeastern face. For northwestern face the seepage has to be controlled. The slip surface is very well exposed on this face
15	164/3 Parapet road landslide	Translational slip	Steep gradient i.e. 60° at the top and 40° at the middle	Clay with angular fragments of sandstone	N 145°	Active	--	-forest and road	Semi wet	Seepage from upslope residential complex of Cantt. probably due to waste water and septic tank disposal and high slope drainage	The high slope artificial drainage from upslope leads to toe cutting thus road failure besides continous seepage from upslope area.
16	Army Station HQ, Cantt area Landslide zone	Rotational slip with debris slide	Moderate slope at the top to steep slope at the toe	Clay with small angular rock fragments of sandstone.	SE	Very Active	110°/19° 220°/56° 195°/77° 150°/76°	Army residential area	Very wet condition	Seepage from Septic tank, heavy precipitation and steep slope	Heavy overburden material with maximum rate of movement of the slide zone in the dip direction. The slip surface is composed of clay stone which is very well exposed in the central zone of the slide. Needs control of high waste water seepage from uphill residential areas of army. There is a need to vacate rest of the occupied residence of army from the slide zone before any [illegible]

S.N	Location	Type of Landslides & Movement	Geomorphic position and slope	Lithology and Material involved	Failure plane	Active/ dormant	Joint pattern	Land use	Hydrological conditions	Major causes	Remarks
17	Kajlot Slide zone	Debris slide with rotational slip. Scar at the crown. (Very old slide zone)	Moderate to steep slope	Clay with small angular rock fragments of sandstone. The boulder and pebbles of sandstones are also present	SW	Active	180°/40°	Residential and agricultural	Seepage, clayey in the middle	Toe cutting by the nala, toe cutting by Dal lake nala in rainy season and seepage	Needs to channelise the natural drain flowing from within the village and restrict local residents not to remove or blast big stones from the Dal Lake Nalla and other drains in order to reduce the speed of the flow during heavy rains.
18	Gujiara Slide zone	Debris slide with rotational slip. Scar at the crown. (Very old slide zone)	Moderate to steep slope	Clay with small angular rock fragments of sandstone. The boulder and pebbles of sanstones are also present	SW	Very Active	210°/ SSE and SW/SW	Residential	underg wet slopes and springs	Natural drain at the west is harmful, toe cutting by Dal lake Nala & water seepage, slope	Needs to check the flow of Nalla in the west, Need to retain the slide from the toe i.e from the base of Dal Lake nalla wich is bit costliest affair and to reduce seepage by controlling drains from uphill or rehabilitate the residents of the village to other suitable site
19	Jogiwara Landslide zone	Debris slide with rotational slip. Scar at the crown. Toppling effect is very well seen. The joint direction acts as the slip surface	Moderate to steep slope	The rock are dipping northeast but highly jointed	NE	Active	-	Forest on one side with residential and road and residential on the crown of the slide	The 'NE' face generally Wet condition one due to seepage from the Tibetan residential complex. This leads to regular subsidence of road	Very high seepage from the tibetan complex of waste water disposal	Urgent need to control the seepage from the tibetan complex, otherwise it not only take away the road but also residential complex situated at the top of the slide zone.
20	Tota rani Slide zone	Rotational slip	Moderate	Clay with angular fragments of sandstone	SSE	Active	--	Residential	Wet	Seepage from the Dal lake and toe cutting	Need to plug the seepage from the Dal lake and retaining of slide mass from the toe beolw colonel House. Very high rate of movement near colonel house and need to rehabilitate some of the houses in the village.

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racks and generally buried under hill slope scree. The scree at the top is covered by a 1-1.5 m thick layer of soil. The slopes have residential building over them. It has been observed in the field that there is very high seepage of wastewater from the Central Administrative Tibetan Complex(CATC), thus creation of swamp in the crown of the slide. Seepage from leaky water pipes and natural drains; chocking of natural drains, hummocky topography and presence of numerous minor scars, cracks, slumps and convex slopes segment in the upper fan section and hill slope scree indicates that the area was also affected by landslide activity in the past(Fig. 10). Some transverse E-W trending cracks are also evident from the surface observations at the slide zone (Fig.11). A displacement in the boundary wall constructed in the area (Fig.12) indicates that it is an active slide zone. Bulging of breast wall and shift of 5-7 cm has also been noticed in the walls of the house of Mrs. Bina Devi. Although Prof. Tandon's house in this locality does not show any sign of failure at present yet the houses located adjacent to his house are found distressed due to slope movement in this zone (Fig.13). The reason for Prof. Tandon's house not showing any failure signs could be the position of swamp area which is located at a relatively lower elevation. Thus, there is no problem of seepage.

The process of mass movement in this section is still continuing as indicated by numerous terraces formed by the creep movement, creation of space between embedded boulders and land. High rate of seepage along the upper slopes and high porosity of surface scree further facilitates the creep movement in the area.

The monitoring of slope movements has been done using 13 benchmarks fixed in the body of the slide zone with the help of a measuring tape. The relative rates of movement in different parts of the slide were assessed using trigonometric survey method. It was found that the extent of movement varied from 5mm to 30 mm. An attempt was also made to monitor the propagation of cracks developed in the ground and in the residential buildings within the slide zone.

The main causative factors for the slide are seepage, septic tank and wastewater disposal from Central Tibetan Administrative Complex as well as inhabitants of Gamru area and uphill slope residential areas. Although this is a very old slide but has been reactivated after a long time due to heavy seepage from the residences uphill in the clay soil, most of the residential buildings on the upslope or downslope are constructed on debris material which consist of dominantly clay with some boulders of sandstone embedded in it. The clay normally absorbs

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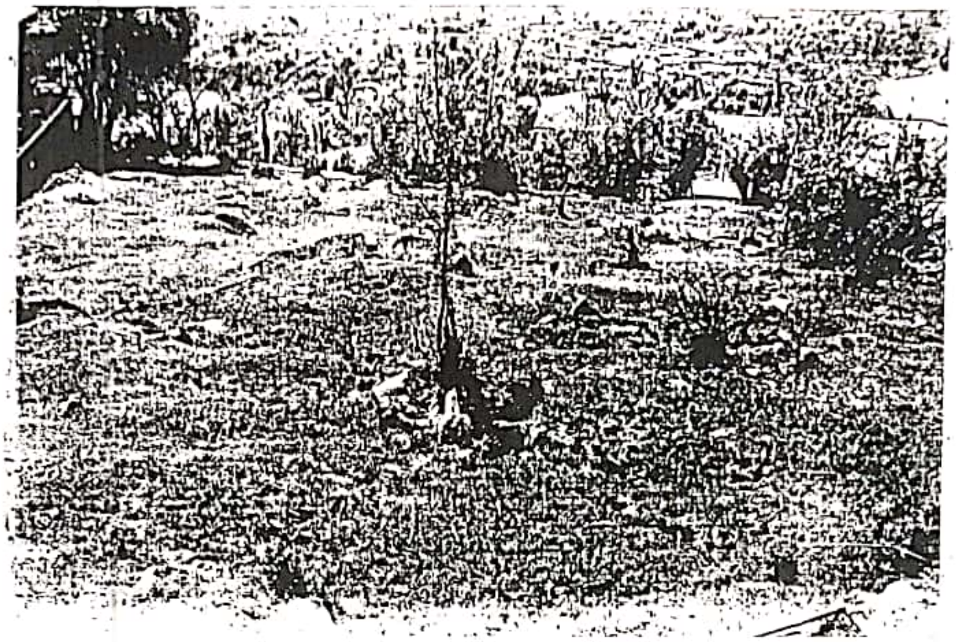

Fig. 10: Swampy land area in Tikka Gamru

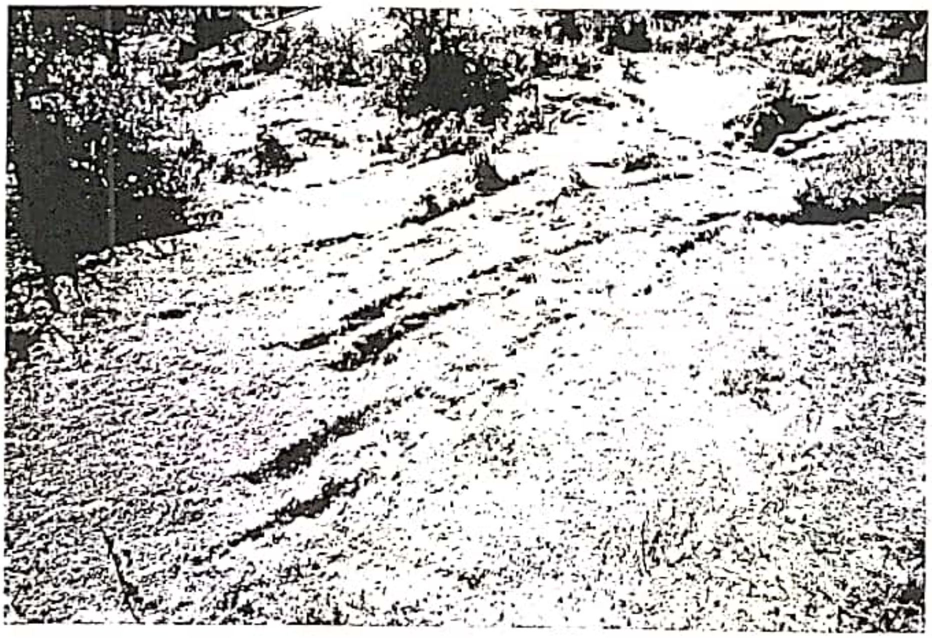

Fig. 11: Development of transverse cracks on slopes in Tikka Gamru

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Fig. 12: Distress in foundation walls due to slope movement Tikka Gamru

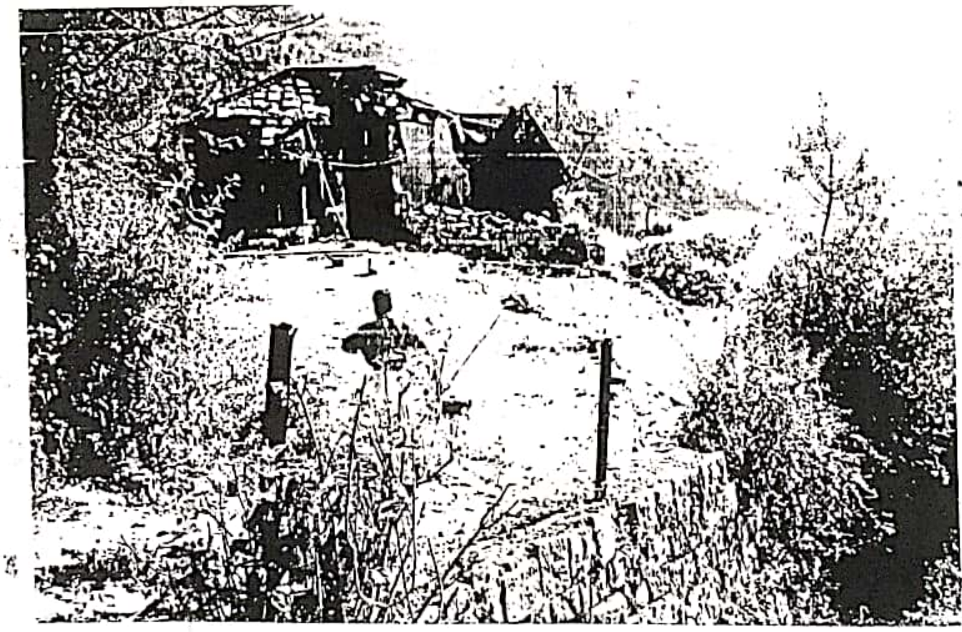

Fig. 13: Building damaged by landsliding in Tikka Gamru

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water and thus leads to solifluction and creep movement in the area. Some of the recent and old constructions shows clear evidences of movements. There is an urgent need to clean up all natural drains; control septic tank disposal and channelise waste water disposal from the Tibetan complex and resident of Gamru, not only to save Tikka Gamru area but also Ram Nagar and Shyam Nagar

D.C. Residence (DCR) Landslide Zone

The affected hill slope lies just 300 m away from Kotwali Bazar adjacent to Municipal Park and is covered with overburden material consisting of debris admixed with clayey and silty soil. The debris has been transported from the hill slopes in the adjoining areas. The length of the affected hill slope from the crown to the toe is approx. 150 meters with maximum width at the crown is from 70-80 meters. Hence the slide appears to be of small magnitude and confined between two natural drains. Although the whole zone of almost 150 m from Municipal Park is a reactivated zone which slided during 1960 and remedial measures were implemented in 1968 after a careful study by geologists. However, presently a zone of about 70m from natural spring located on the northern side of road has been reactivated during 1997. The crown of the slide is continuously heading northwards since then. The slide is of rotational type but translational slips and bouncing movements have also been noticed. The main direction of slope movement is SSW. During the field investigations, a number of deep transverse and longitudinal cracks have been noticed in the body of the landslide. The road in the slide zone has subsided due to undercutting by a natural drain and overloading of the crown. The features of subsidence and erosion can be witnessed in Fig. 14. Since the hill slopes are highly saturated the saturation of unconsolidated soil reduces the frictional resistance amongst the particles by decreasing the force of cohesion which holds the soil particles together under optimum moisture content. The movement of rainwater and seepage from natural drain upslope, which percolates into the overburden soil, is obstructed by clayey matrix present in the soil. This results in the development of pore water pressure in the body of soil mass and thus decreasing the shearing resistance of the material constituting the slope. The choked drains below the D.C. residence garrage also hinder the smooth flow of water. Further, observations during field investigation, revealed that within one month period, there was a land subsidence of about 3-4 mt.(Fig 14) which caused a problem to vehicles plying on this road. The tilting of trees and bulging of the retaining walls as depicted in the photographs (Fig.15) . The sequence of photographs (Fig.14-21) taken from July, 1998 to

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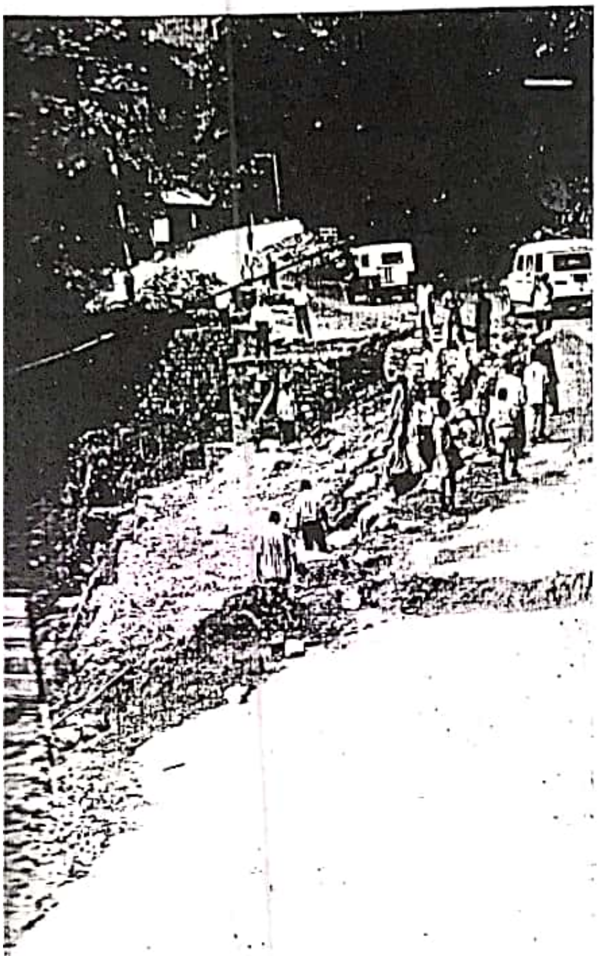

Fig. 14: Road subsidence (3-4 m) in DCR slide zone

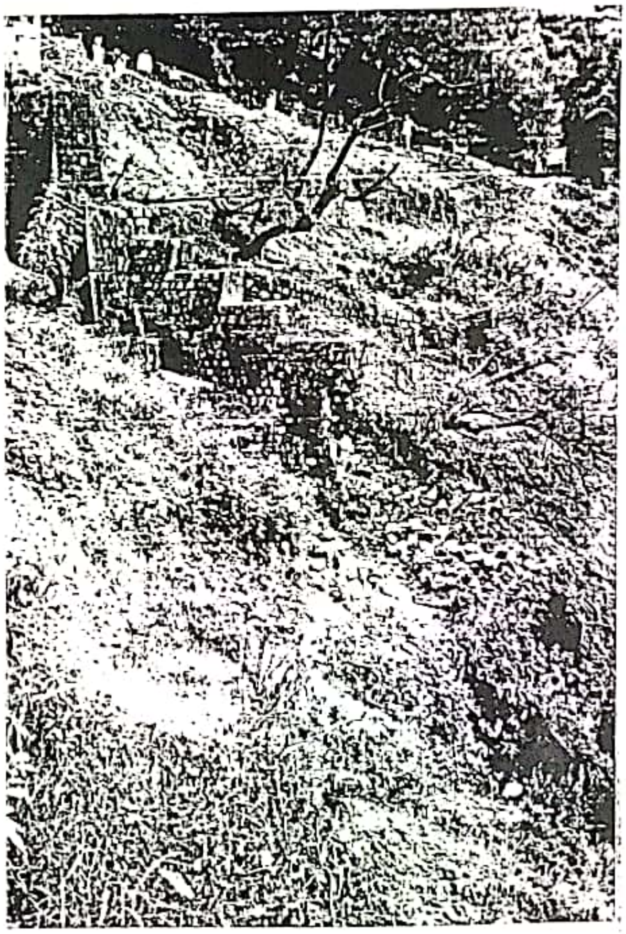

Fig. 15: Tilting , uprooting of trees & bulging of walls in DCR slide zone.

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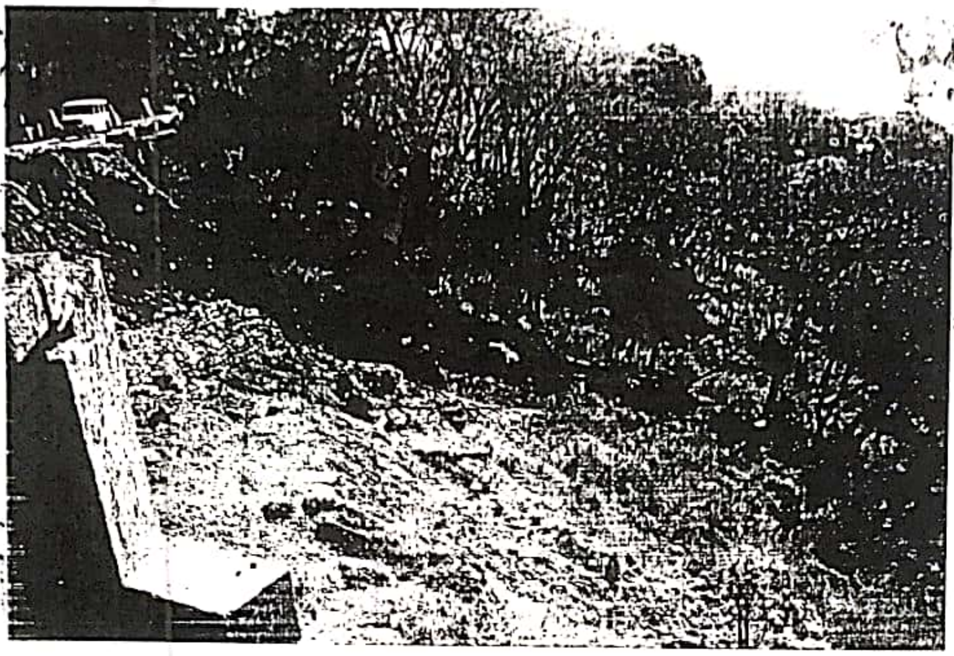

Fig. 16: Impact of Overloading at crown level - Failure of old retaining wall in DCR slide zone

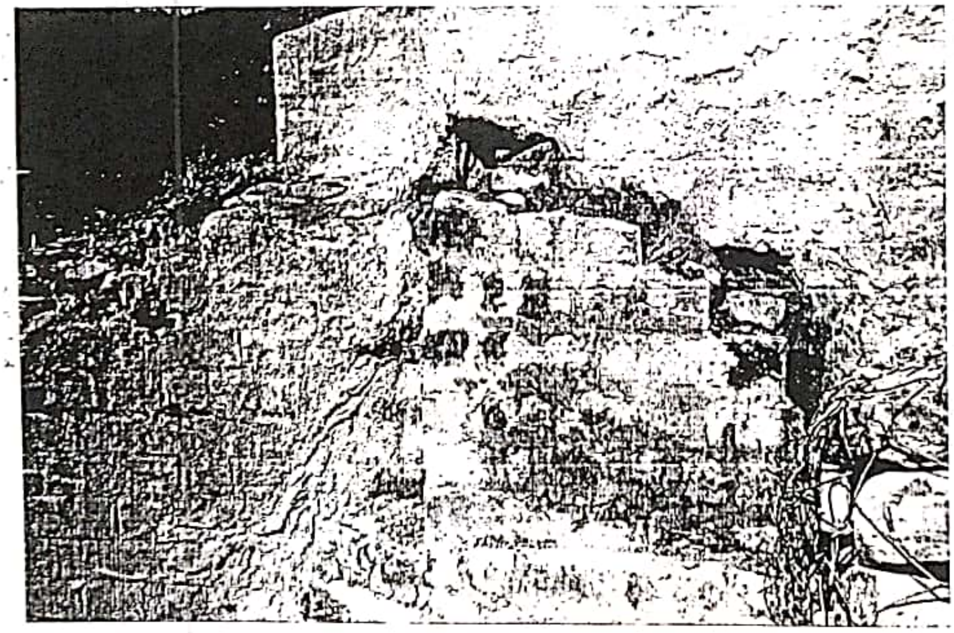

Fig. 17: Subsidence in support walls of a road bridge due to sliding activity in DCR slide zone

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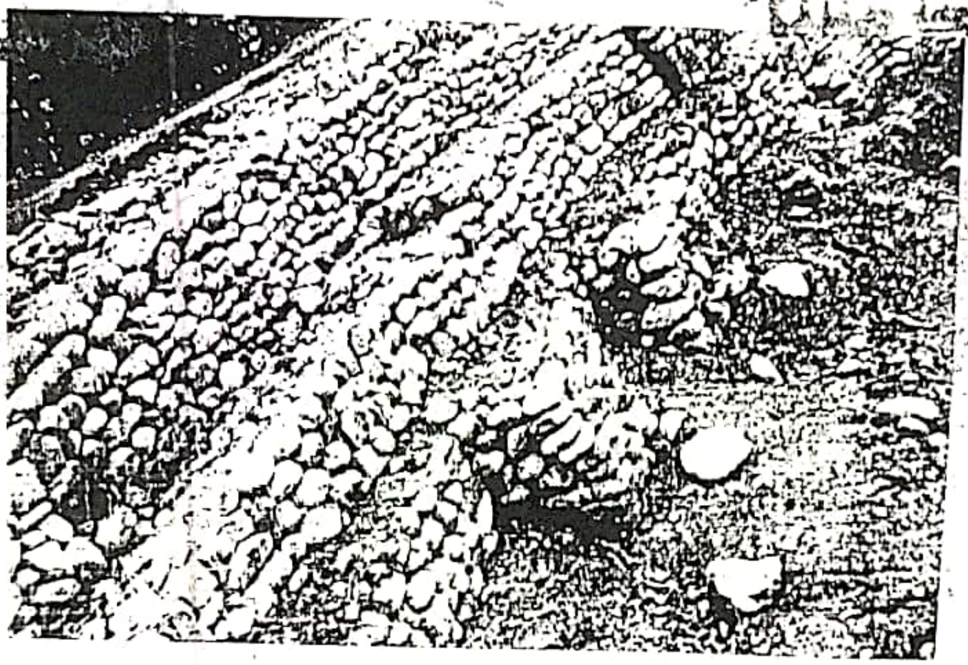

Fig. 18: Improper overloading at crown level to control landslide in DCR slide zone

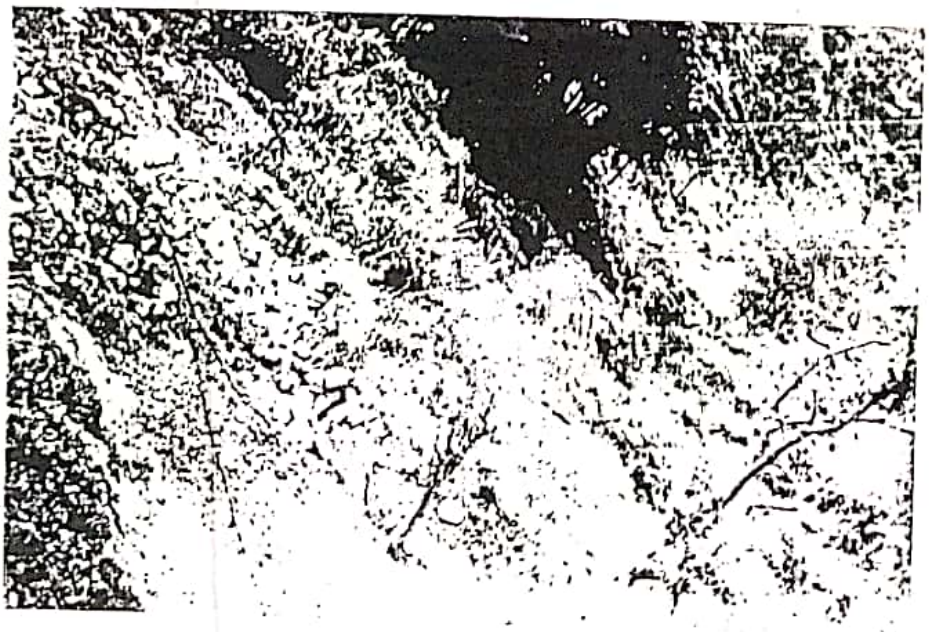

Fig. 19: Uprooting of trees, loss of vegetation and failure of wire crated stone wall in DCR slide zone

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Fig. 20: Overloading of crown zone causing damage to road in DCR slide zone

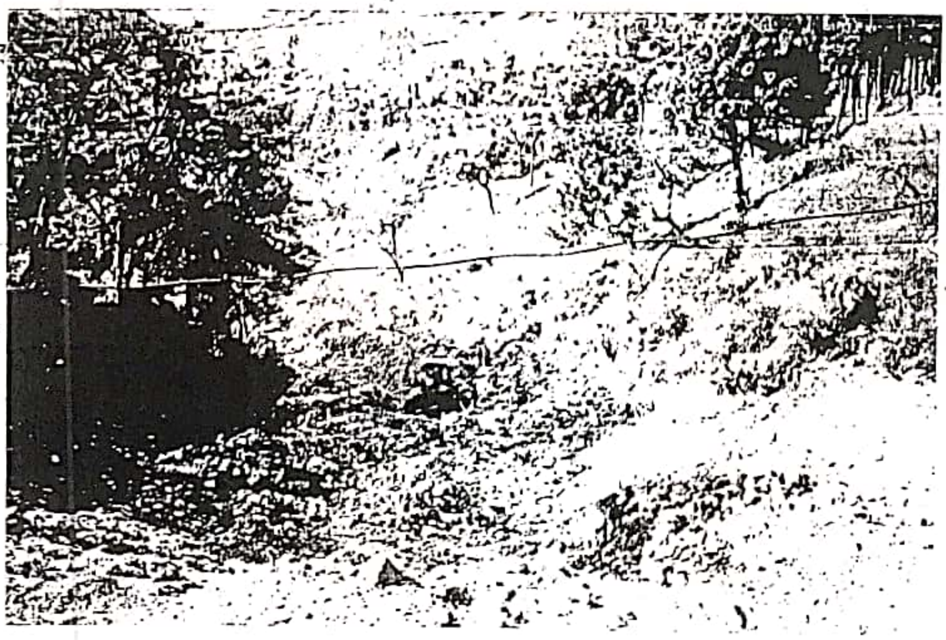

Fig. 21: Development of transverse cracks and damage to lifelines in DCR Slide zone

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Nov. 1999 clearly reveal the history of this slide during the past three years. [illegible] old landslide zone but has been reactivated during 1997 and heavy rainfall during the monsoon season acts as the main triggering agent. From the field observations, it has also been noticed that the drain to the west of the affected site has been lined with cement but has been damaged at number of points which also helps in seepage. The slide zone was retained by constructing retaining wall in six steps from toe to the crown, whose remnants are still existing at the site. Even the area above the municipal park and just below the open lawn of D.C. residence have shown signs of subsidence and the area of Municipal Park has already shows clear signs of subsidence. This park has also been affected due to side cutting by natural drain in rainy season.

The major causative factors are seepage from the drainage from upslopes, toe cutting by natural drains at the base and steepness of slopes. The repeated loading of the crown and regular seepage following rainfall also accelerates the movement of the slide zone.

The first and foremost remedial measure is to channelise the natural drain through the use of hume pipes of appropriate diameter in order to check complete seepage. The hume pipes have to be set up from the top (near D.C. Residence, Garrage) to the bottom of the slide zone and then to divert flow of water in a stepped channel in order to reduce the pressure of outflow. This will also avoid further toe and side cutting in the body and at the base of the slide zone. Construction of RCC retaining wall with weep holes in five to six steps from the toe to the crown will also help to stabilize this zone. The present measures taken by the PWD needs necessary modification; 1) to shift the lower most retaining wall further down to the toe level 2) to plug the seepage of drain from the top(just besides D.C. residence garages) to the toe of the slide zone in order to mitigate further problem 3) The water from the drain has to be channelised and dropped at the bed of stream.

M.P. Residence (MPR) slide zone

The M.P. Residence slide zone started from the Tin Shed at the residence of Smt. Chandresh Kumari and extends down to the Dharamsala-Mcleodganj road in the slope direction (N305°). The total width of the slide zone is 28 m and covers an area of 0.0187 sq. km. It is a rotational slide. This slide zone comprises clay with small rock fragments, pebbles and cobbles of sandstone. Clay is dominant litho-unit of this slide zone, having a moderate slope covered by agricultural and residential land. The upslopes of this zone are occupied by large inhabitation of Tibetan Complex and the waste water disposal and septic tank discharge from the uphill slopes

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leads to greater seepage in the ground. The seepage can be seen from the house of Mr. Goverdhan Lal (Fig.22). A very deep (about 1 m) surface crack trending N275° with width of 16 cm and length 34 m has been noticed and within one year, the area has subsided from 30cm to 2mt.(Fig.23). The transverse and longitudinal cracks (Fig. 24) in the body of the slide zone have been noticed which have lead to subsidence effect, evident from the field observations at the crown and at the foot level of the slide zone. This is also an old slide zone showing a high degree of movement indicated by the subsidence of road below M.P. residence and damage to the house of Mr. Goverdhan Lal since 1984. Still the activity is going on and recently leveling of the road has been done by overloading the crown with additional soil brought from other areas (Fig. 25). This will not only accelerate the rate of movement but also result in mudflows during rainy season, thus posing heavy risks to economy as well as life of the residents downhill of this slide zone.

The field observations at the toe of the slide zone also reveal that it is a rotational slide with highly wet conditions (Fig.22) and the slope becomes very steep below the house of Mr. Goverdhan Lal. The surface cracks of width upto 18 cm. have been noticed on the upslope direction of Mr. Goverdhan Lal's residence.

Therefore, in order to restrict the slope instability in this zone, it is necessary to channelise the wastewater disposal and also the rainwater along the slope of the mule path situated just above the M.P. Residence. Simultaneously, the septic tank disposal also needs great attention for its proper channeling through pipes. Apart from the above, the seepage from the natural springs situated on the upslopes of M.P. Residence need to be checked.

Station Head Quarters

This slide zone is located on Dharamsala – Mcleodganj road at about 7 Km from Dharamsala Town. In the vicinity of the slide zone, Brigade Head Quarters of Army Cantt. is located and some of the army residences are situated within this slide zone. It is a rotational slide involving debris, with moderate slopes at the top and steeper slopes at the toe level. Clay and small angular fragments of sandstones are the main constituents of the overburden material, which is almost 5-7 meters in the area. It is a very active slide zone and has affected an area of about 0.108 sq. km. Near parapet 166/8, the sinking of road, severe damage of the artificial concrete drain is very much evident(Fig. 26). The infilling on the road and construction of several retaining walls using boulder wire crates shows that within a year, this road has subsided upto

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Fig. 22: A crack in wet slope mass, covered with slided debris in MPR slide zone

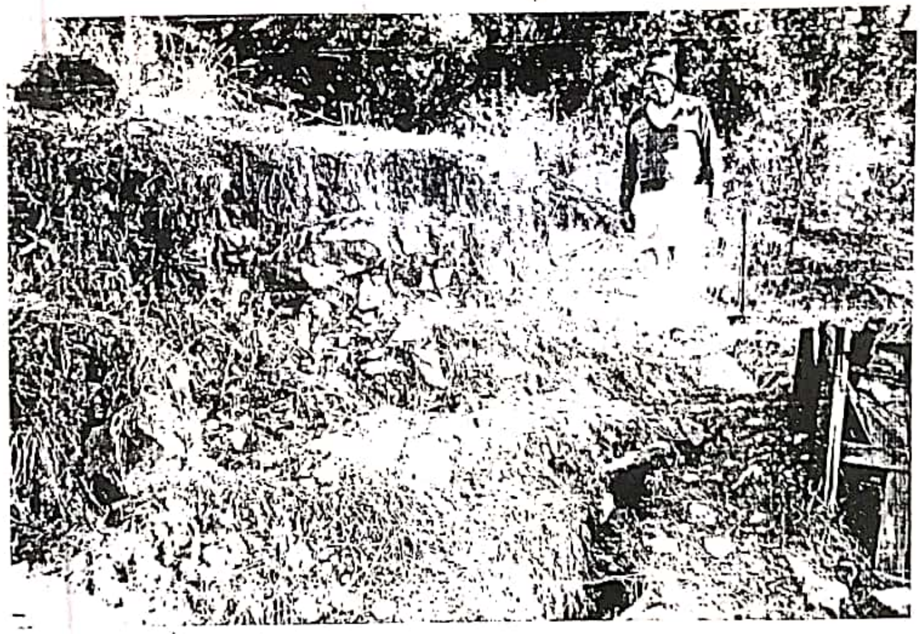

Fig. 23: Development of deep transverse cracks in the slide zone in MPR slide zone

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Fig. 24: Longitudinal and transverse cracks in MPR slide zone

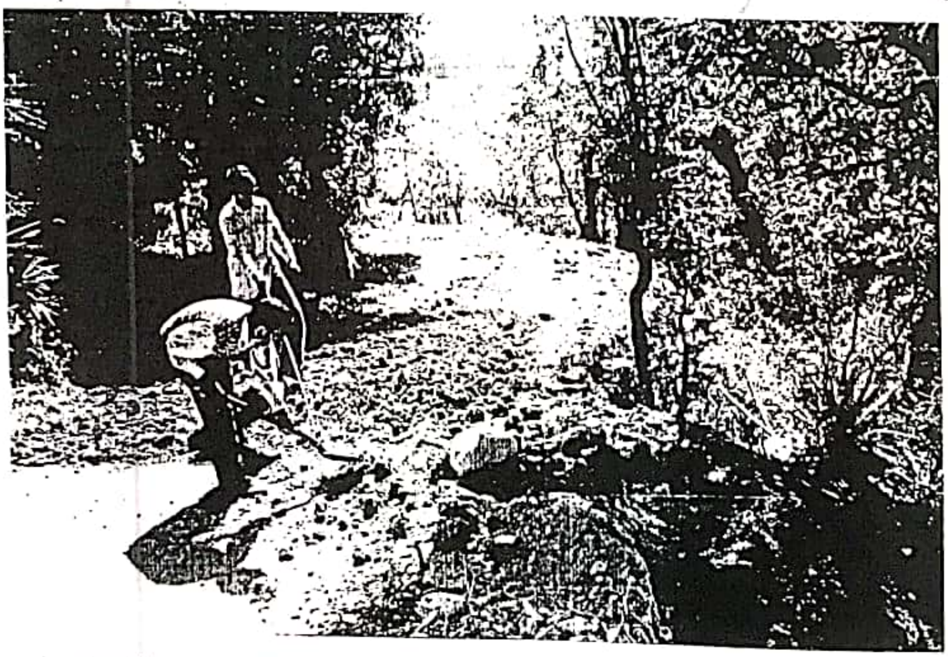

Fig. 25: Road subsidence and overloading of crown zone with soil, which may result in mudflows during rains in MPR slide zone

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3m. This slide zone can be divided into three major zones, i.e. Crown zone with road , Middle zone with residential colony where a boundary wall of the colony has been badly damaged and one can see a shift in the alignment of the boundary wall constructed below the constructed houses (Fig. 27) and a lower zone partially under residential quarters and partially under forests. In the lower portion of the slide zone an artificial drain has been found displaced by from 3-5 m (Fig. 28), thus, showing a very high rate of movement. The slip surface also passes through claystones which is very well exposed at the toe of the slide zone where one can find huge amount of water gushing from the slip surface although the upper slopes are damp to wet in nature. Since there is already seepage at the slip surface which has generated number of longitudinal as well as transverse cracks on the surface (Fig. 29). A heavy rainfall in the area always triggers land movements. Side cutting and toe cutting during rainy season also promotes failure.

The major causative factor of this slide zone is very high rate of seepage from the septic tanks, waste water disposal from upslide residential colony of the Army. So there is a need to channelise this water and also to redesign the existing concrete channel from Army Garrage to the slide zone in order to reduce the runoff pressure that the damage occurring during monsoon season in the area is reduced.

Thus, if proper remedial measures are not taken, the time is not very far away when the residential colony and the important Dharamsala –Mcleodganj Highway will give way and there will be a severe problem of transportation and risk to life and economy of the region. The urgent need of the hour is to channelise the septic tank sewerage and waste water disposal from the Army Cantt. area , septic tank disposal of the residential colony with in the landslide body and to lay down a network of concrete channels along the upper side of road and slopes and distribute the water in number of drains to downslopes in order to reduce the run-off pressure during rainy season. A complete plan of drainage network can be worked out with the help of local engineers at site in future before the next rainy season begins.

Totarani

This slide zone is located south of Dal lake along the Dal Lake Nala. It has rotational slip on moderate slopes. The slopes comprise clay with angular fragments of sandstones. A nala coming from Dal lake is passing at the toe of this slide zone and causes toe erosion. thus, accelerates the sliding movement. The slips on the cemented road are a clear cut evidence of the

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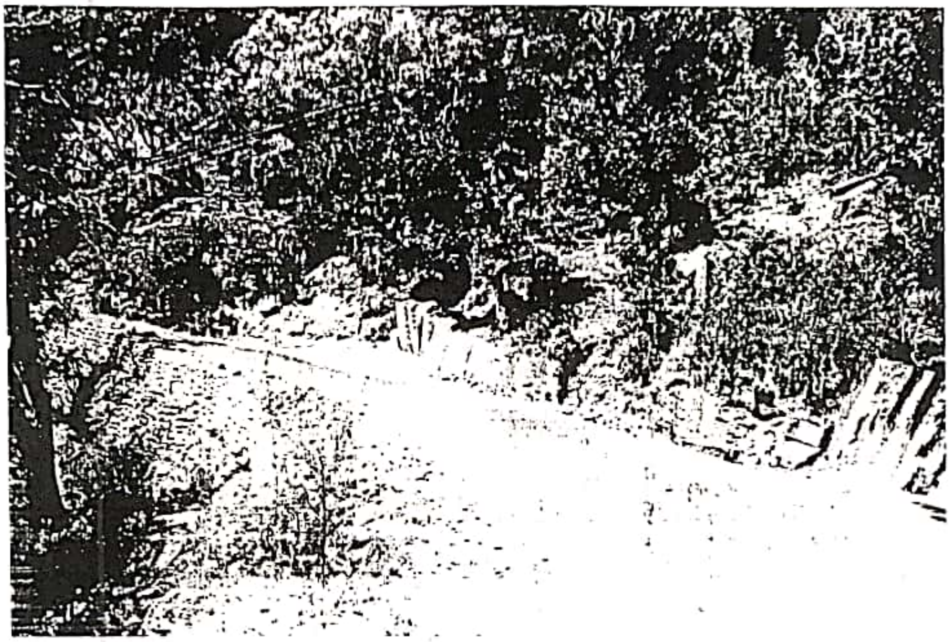

Fig. 26: Damage to artificial cemented drains on roadside Station HQ slide zone

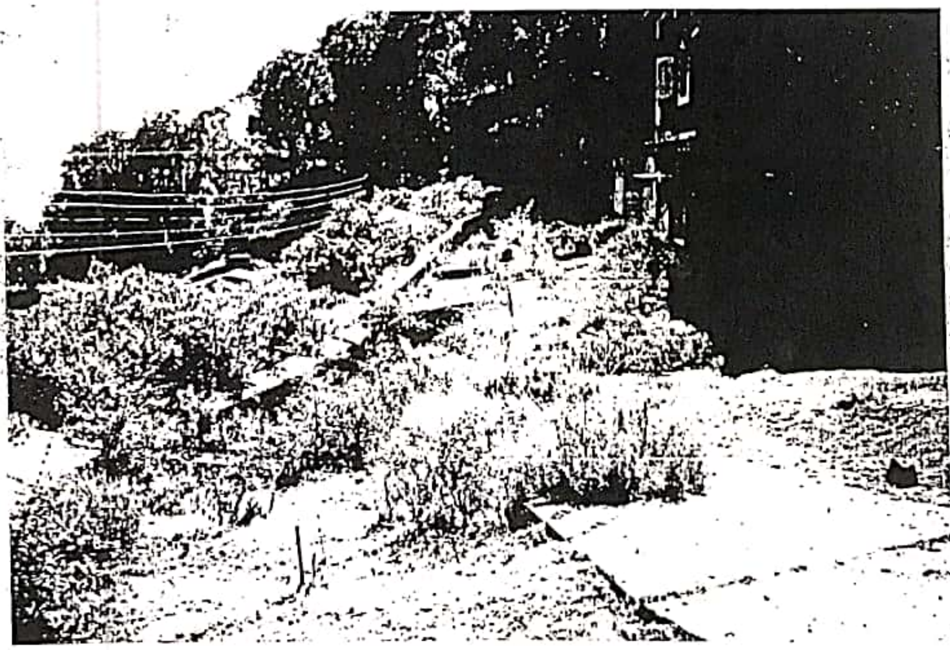

Fig. 27: Displacement in boundary walls of Station Headquarter residential buildings

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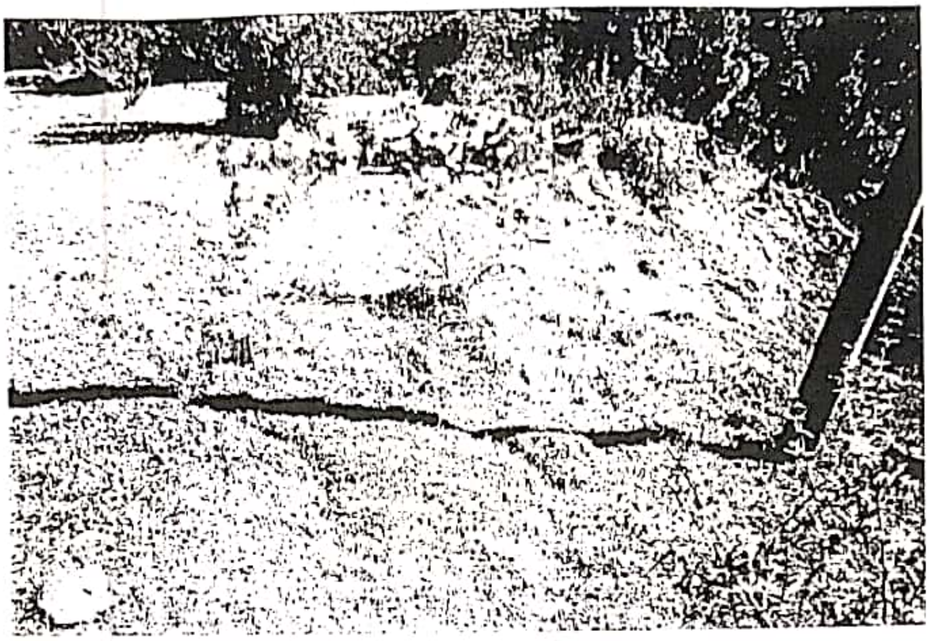

Fig. 28: Development of transverse and longitudinal cracks due to creep movement in Station Headquarter slide zone

Fig. 29: Displacement (5 - 7m) in artificial drains at Station Headquarter slide zone

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mass movement (Fig. 30) besides damage to house of Pandit residing in the area (Fig. 31) and movement was noticed in the house of Major S.S. Nepali. The main building of the Major Nepali has moved south –southwest whereas his bathrooms also indicates shift in their position, which is very well evident from the position of pucca drains in this house and narrowing down of the footpath from 4 feet to 2 feet, located between house of Mrs. Chandrawati and Major Nepali on the west of a natural drain. Even the other parts of the building like pillars attached to roof shades and roof axis on the top of the house have shown gaps due to downward movement of the slope mass in this area. On the northeast side of the natural drain and west of Dal lake nala, the area is moving downwards i.e. in the slope direction.

The major causative factor of the slide is the high seepage which is gushing out within the body of the slide zone (Fig. 32) from Dal Lake. Although, the local seepage of the residents of the area and septic tank disposal allows the mass to move slowly but the seepage from Dal lake and toe cutting by Dal lake nala aggravates the problem. The area is under high risk in the present situation as it is occupied by several house hold units.

The remedial measures like proper sewerage disposal and appropriate drainage controls for uphill slope water along the road following slope, proper disposal of daily waste water to be organized by the local residents and plugging of seepage from Dal lake requires due attention. The landslide hazard map and risk map shows very high hazard and very high risk to the residents of this area.

Jogiwara slide zone

This slide zone is located on Khara Danda road connecting Dharamsala-Mcleodganj. The overburden material of this slide zone comprises clay with rock fragments of sandstone having moderate to steep slope from the crown to the toe. Along the middle of the slide zone longitudinal and transverse cracks have developed. The presence of benches, cracks, minor scars and small water ditches just below the hill slope confirms an earlier old landslide (Fig. 33). The subsidence of the road can be witnessed from Fig 34, thus, showing an active slide zone. The footpath leading to the village Gamru has also been disrupted due to the movement in this slide zone. This shows a high rate of movement.(Fig.35). The titling and uprooting of trees also indict a high degree of movement. The bedrock is also exposed in this slide zone but the dip of the rocks is north 65° whereas the slope movement direction is north 110° with a slope angle of 36°. The effect of joints in the activation of landslide can not be ruled out as the rocks are highly

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Fig. 30: A shift of 10 -12 cm in the cemented path in Totarani village

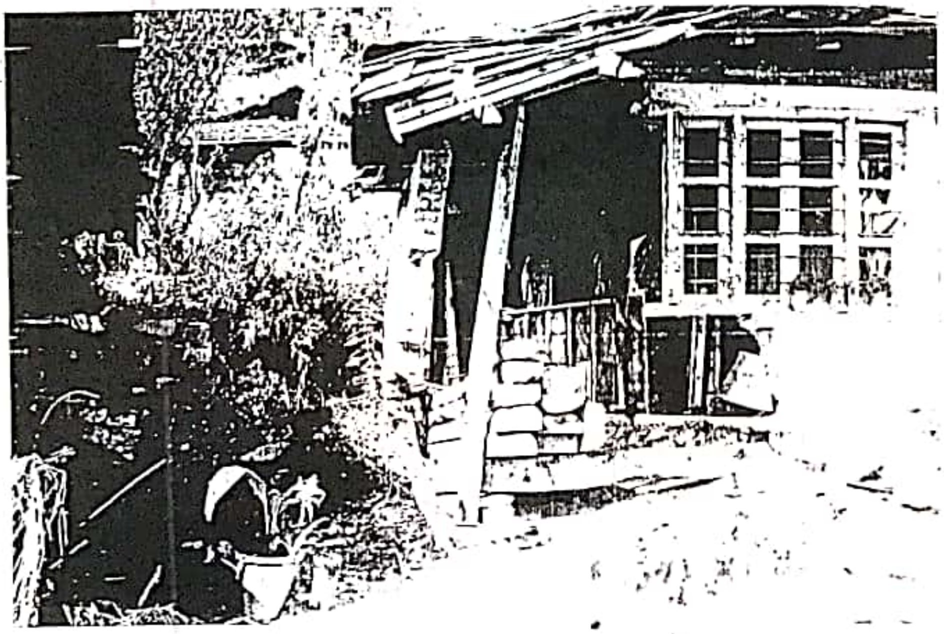

Fig. 31: Floor subsidence and building damage due slope failure in Totarani village

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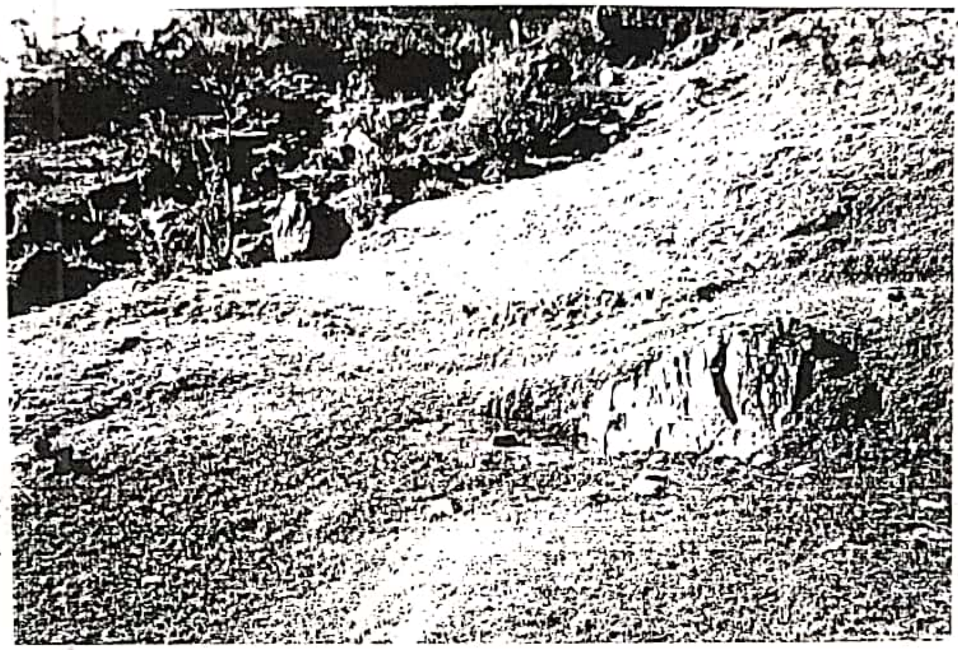

Fig. 32: Accumulation of water due to seepage from slopes in Totarani village

Fig. 33: Water accumulation due to seepage from slopes in Jogiwara slide zone

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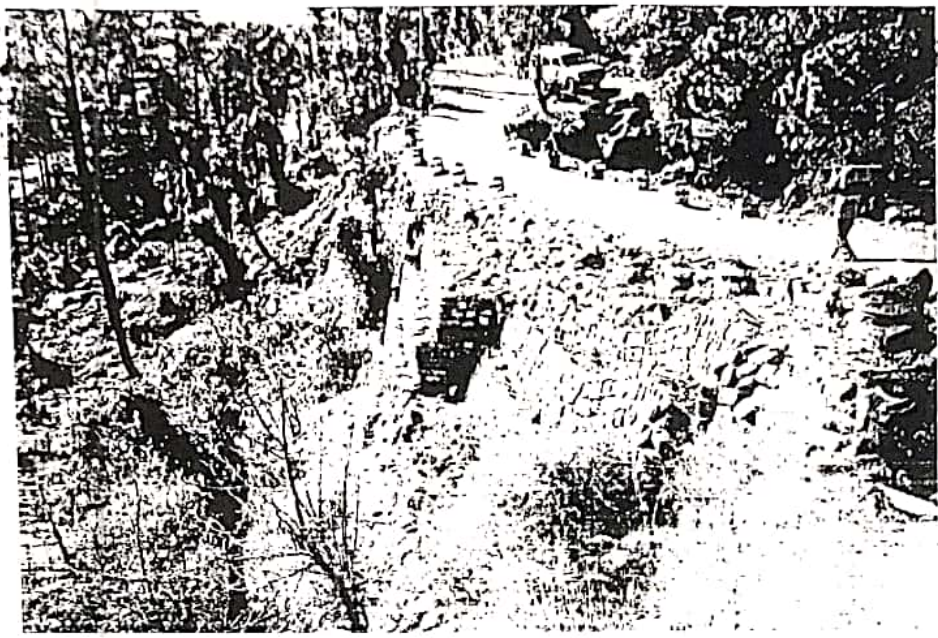

Fig. 34: Curvature in retaining walls indicating ground subsidence in Jogiwara slide zone

Fig. 35: Tilting of trees and disruption of road alignment in Gamru village in Jogiwara slide zone

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joined and one joint plane follows the direction of movement. The overburden material varies in thickness from 1-5 m. This slide zone is again of rotational type. Most of the land cover is either agricultural or forest, however the crown zone of the slide has residential buildings which are feeding the major seepage in the slide zone. At the same time the runoff during rainy season and its flow due to high hill slope at the crown also helps in accelerating the mass movement.

In the Jogiwara slide zone, the seepage from wastewater disposal and septic tank disposal is the main causative factor and rainfall only triggers or accelerate the movement. It has also been noticed in the field that the Hume pipe fitted below the road to drain out upslope water has been left open in the body of the slide zone which also cause heavy soil erosion and seepage and leads to sliding. In order to reduce the movement in this slide zone it is necessary to plug the seepage and divert the natural drain in the hume pipe so that there should not be any seepage in the body of the slide zone. Secondly the septic tank disposal and wastewater disposal of the Dalai Lama Temple Complex has to be channelised with proper sewerage system in the Dharamsala township.

Other Slide Areas

Besides the above mentioned major active slide zones, other slide areas which have also been affected due to seepage problems are Kajlot landslide, Gujiara slide zone, Barakoti Slide zone, Tira Line slide zone, Parapet 163/3 slide zone, and in the Cantt. area of Tira Lines opposite to Totarani. As described earlier, these slide zones have also been affected due to seepage problems, sewerage and wastewater disposal and toe erosion. The Kajlot and Gujiara slide zones with their toe tapering into Dal lake nala are badly affected by toe cutting by these natural drains, (Fig. 36). However, the Gujiara village is very badly affected because of seepage from the uphill slopes and toe cutting of Dal lake nala. It, therefore, requires immediate steps to either relocate the villagers of Gujiara or plug the seepage from uphill slopes. At the same time, the sewerage disposal from Cantt. area opposite Totarani and the Kajlot occupants themselves result in mass movements in the Kajlot village. In the Kajlot village, a number of longitudinal and transverse cracks have also been noticed in the northeastern side of Kajlot village affecting the inhabitants and the structures present in the area. These slide zones have also rotational component and require immediate steps to plug the seepage from sewerage disposal.

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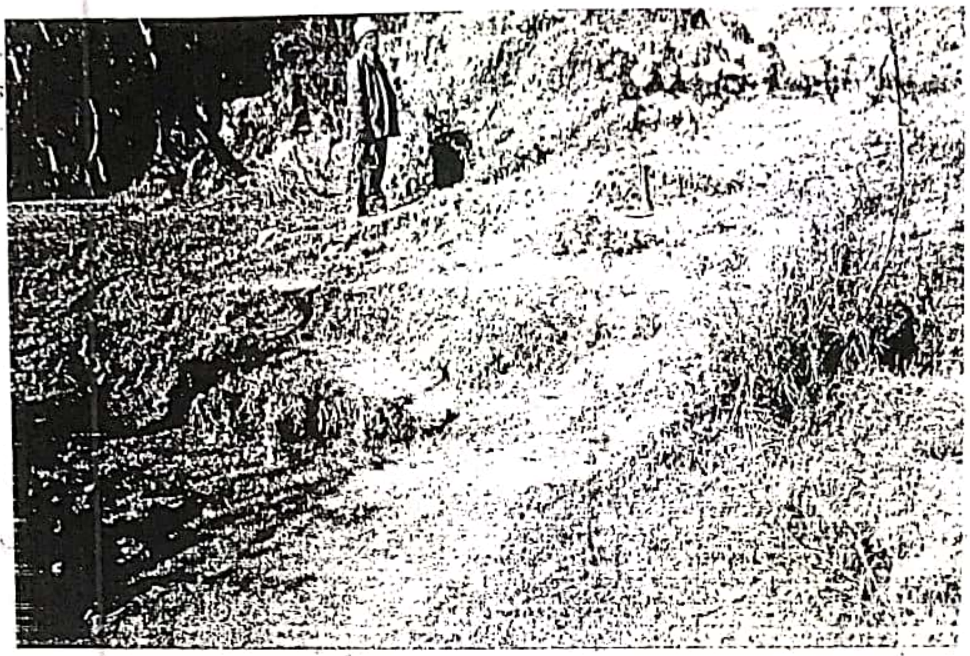

Fig. 36: Presence of benches and cracks indicating slope failure in Kajlot village

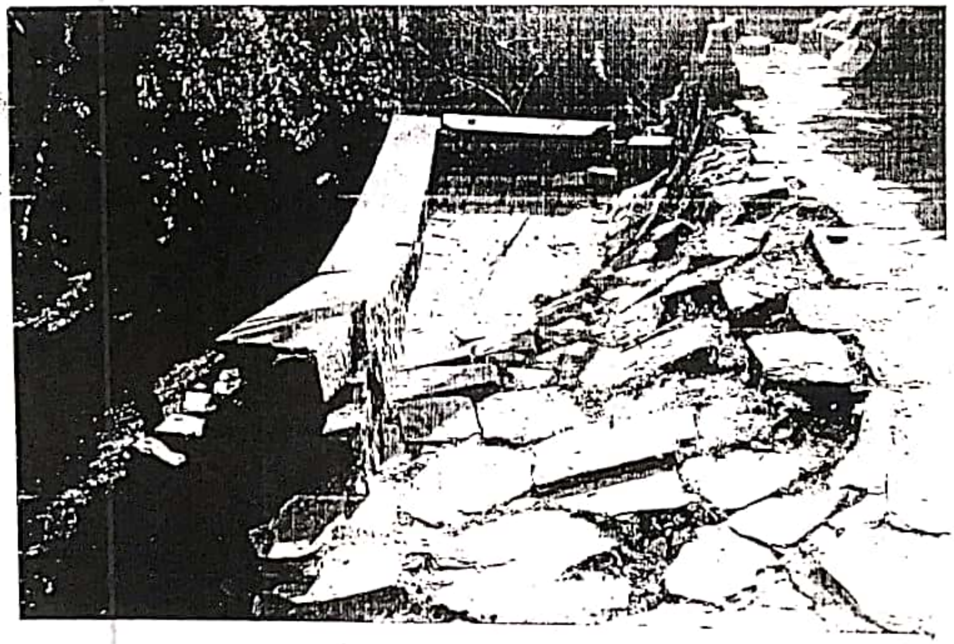

Fig. 37: Subsidence of floor and bulging of walls in Barakoti slide zone

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The Barakoti slide zone and the parapet 163/3 zone have affected the road and the village Barakoti. Fig. 37 shows a clear cut displacement and subsidence of about 1 - 2 feet in the boundary walls of this village, as indicated by the distresses here. At the same time, the upper portion of the village Barakoti above which the main Dharamsala – Mcleodganj highway is located shows prominent scars and benches of land mass in the slide zone (Fig. 38), thus, making the road more vulnerable to the mass movements ; posing high risk to the traffic. On the other hand the rainfall runoff from the Cantt. area to the road passing at parapet 163/3 causes much damage due to toe erosion (Fig. 39). In this slide zone, the major important aspect is to control the outflow of runoff in such a manner so that it should not be released just at the toe. It has been observed that almost all natural drainage channels passing below the road, no one has been given a proper treatment for flow of run-off water and all the outflow has been left on the slope thus, leads to toe cutting. Thus, it is causing much damage during rainy season to the Dharamsala – Mcleodganj highway.

CAUSES OF FAILURE

The Dharamsala area represent an old landslide zone and there are a number of factors contributing to the movement of hill slope of Dharamsala township . The main factors are. 1) geology 2) topography, 3) high slope gradient 4) thick loose soil deposits made up of clayey material mixed with nonuniform cobbles and blocks and 5) hydrological conditions. The Dharamsala town is located between two major thrusts i.e. MBT in the north passing through Bhagsu Nath, Dharmkot and Bal village, north of Naddi in the NW-SE direction and the Drini Thrust in the south, which passes below village Garoh and Sikoh in the NW-SE direction. These two tectonic thrusts are the imbrications of Main Boundary Thrust and a number of splays have developed in between these thrusts thus, causing lot of tectonic movement in the area. Due to tectonic movement, the rocks of Dharamsala Group have been highly deformed, folded and fractured. The fracturing of rocks and presence of young loose material coupled with high seepage due to sewerage and wastewater disposal leads to very high landslide hazard. The active nature of the thrusts and faults is also reflected by the repeated occurrence of moderate (M=5-6) earthquakes in the Dharamsala area e.g. Dharamsala earthquake of 1968, 1978 and 1986 apart from one great earthquake in 1905 of magnitude 8.0. Besides these thrusts, the presence of a number of transverse faults and development of joints in the rocks of Dharamsla Group made up of Sandstones and shales also decreases the shear resistance, thus, allow the mass to move along

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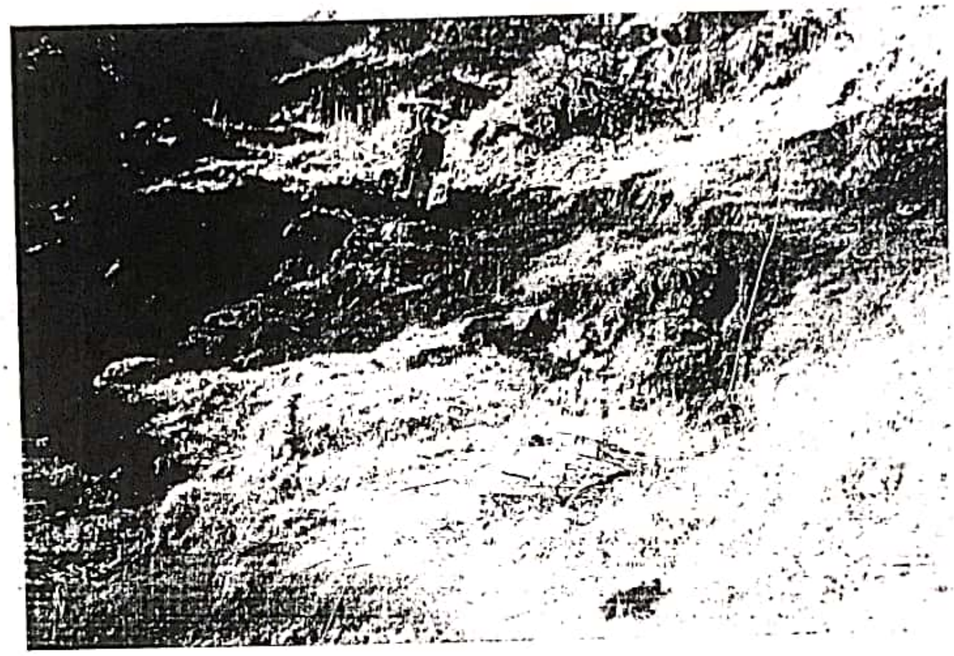

Fig. 38: Crescentic scar and cracks in Barakoti slide zone indicate slope movement

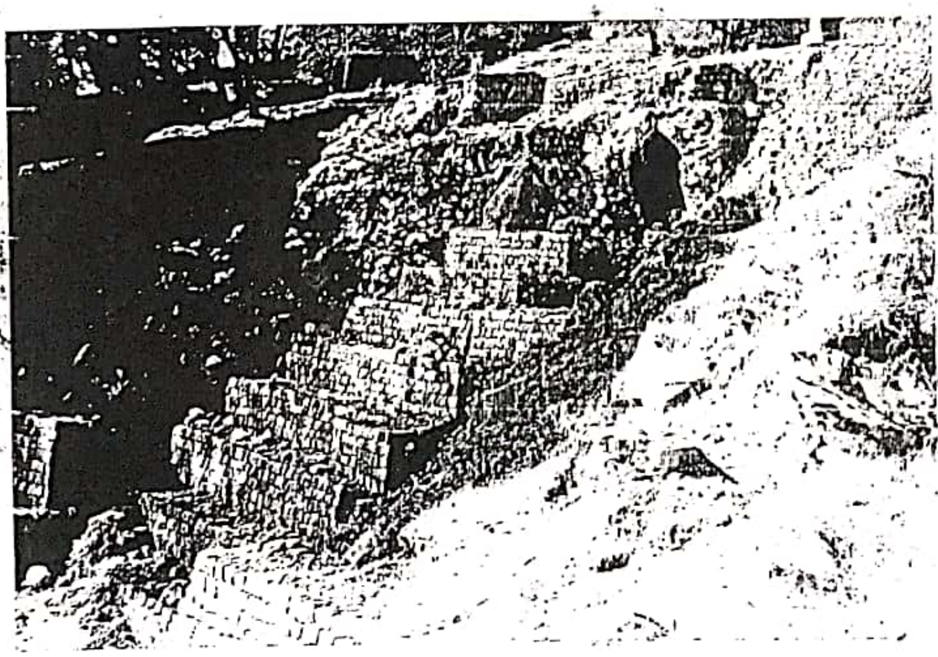

Fig. 39: Erosion at parapet 163/3 slide zone

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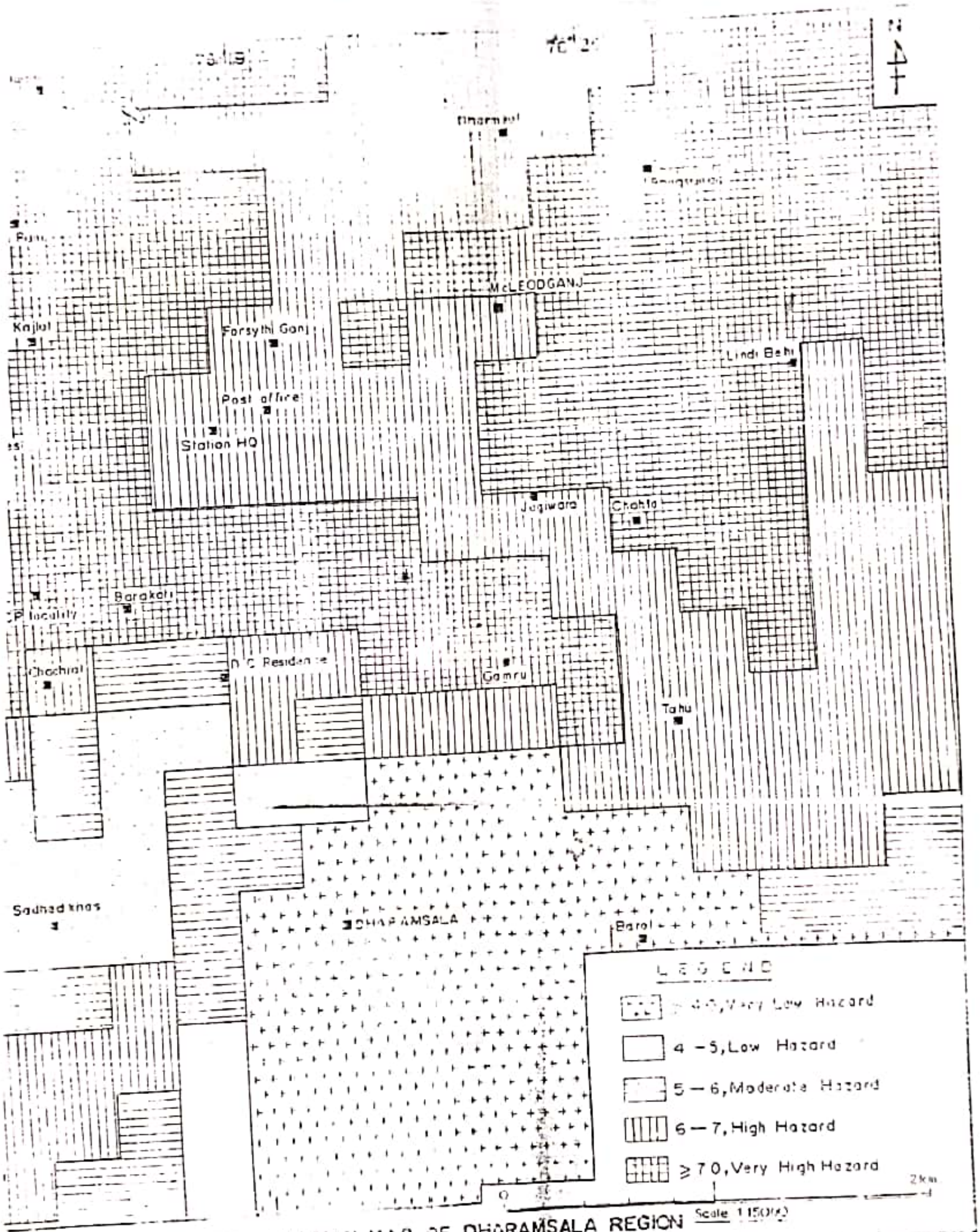

LANDSLIDE HAZARD ZONATION MAP OF DHARAMSALA REGION

Fig 40

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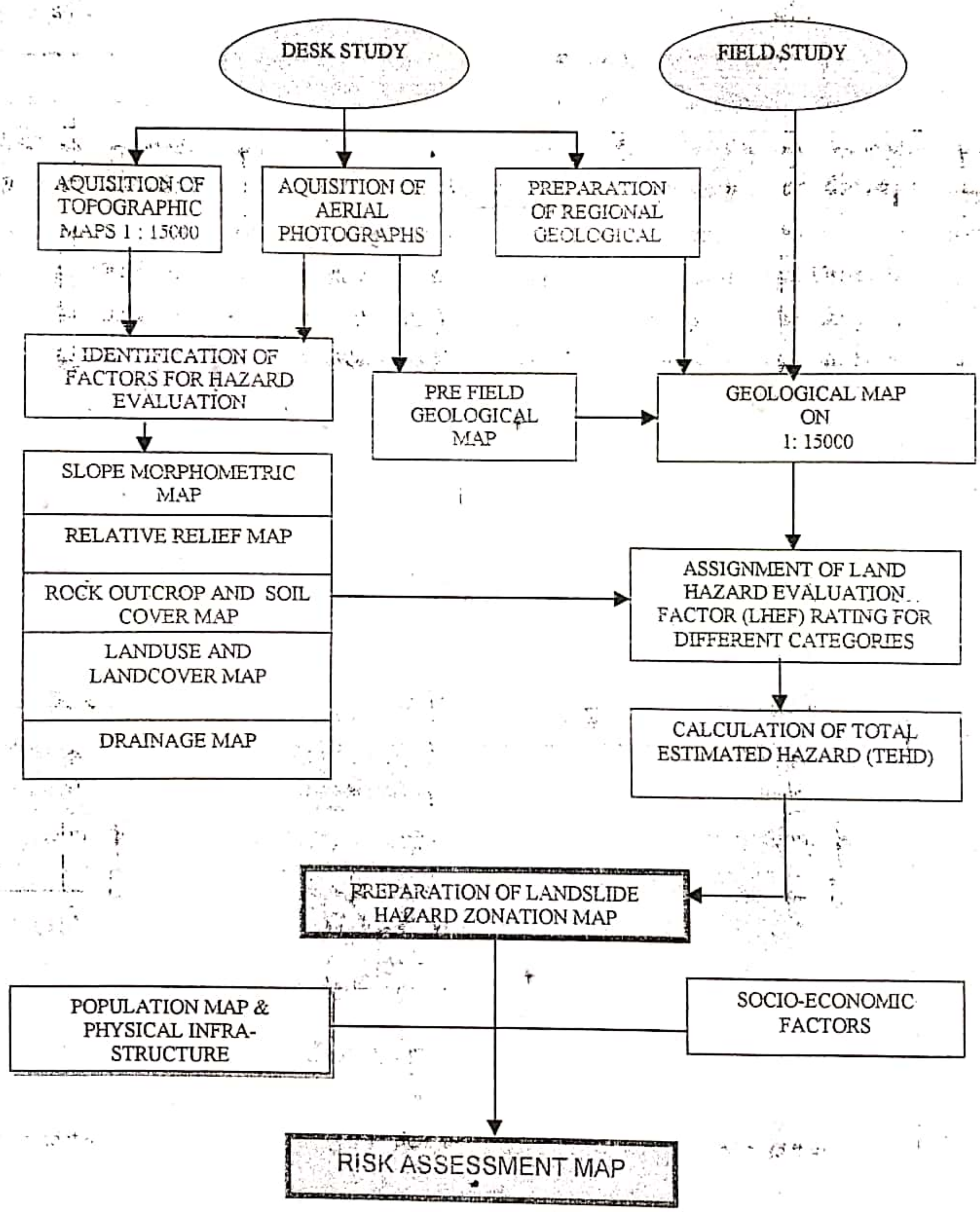
Fig. 41: PHASES OF ACTIVITIES FOR LANDSLIDE HAZARD ZONATION AND RISK ASSESSMENT



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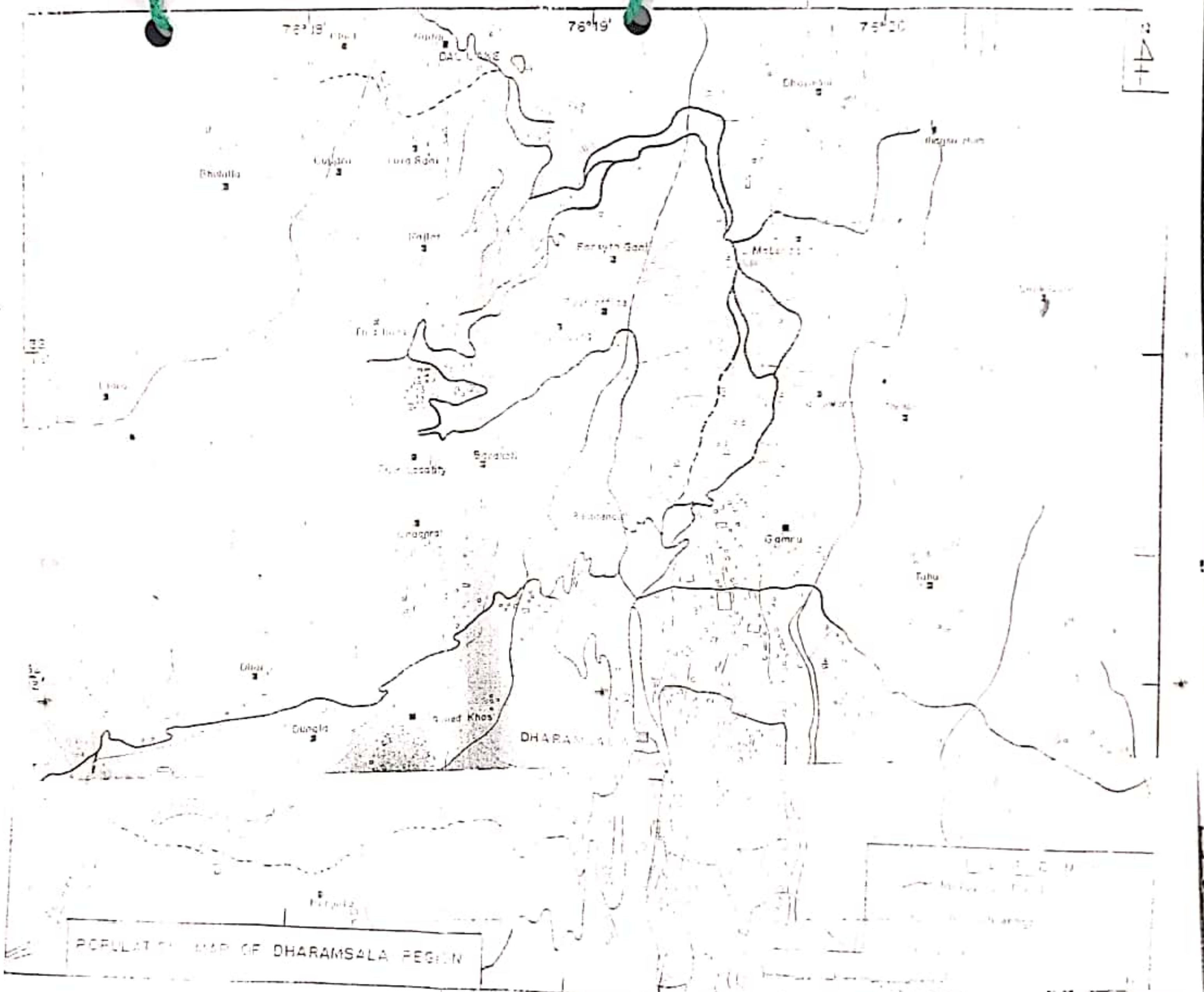

POPULAT[illegible] MAP OF DHARAMSALA REGION

landuse planning and the

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risk factor has been thus, evaluated as a product of the degree of potential hazard and vulnerability of the elements therein. The following risk matrix (Table-3) has been used for classifying the terrain into different risk categories.

Table 3: Landslide Risk Assessment Matrix

Hazard ⇒/ Vulnerability ⇓	Very High hazard	High Hazard	Moderate Hazard	Low Hazard	Very Low Hazard
Very High	VHR	VHR	HR	MR	LR
High	VHR	VHR	HR	MR	LR
Moderate	HR	HR	MR	MR	LR
Low	MR	MR	LR	LR	VLR
Very Low	LR	LR	LR	VLR	VLR

Map analysis

A perusal of the landslide hazard zonation map (fig. 40) indicates that the northern slopes are relatively more unstable as compared to those in the southern part. It has been found that out of the total land area of 35.91% sq. km., about 32% falls under very high hazard zone, 31% under high hazard zone, 7% moderate hazard zone, 85 % low hazard zone and rest of the area(i.e. 21%) has very low hazard.

Similarly, an analysis of the landslide risk assessment map (Fig.43) indicates that 17% area has very high risk whereas 32% area has high risk. About 23% area is covered under moderate risk , 5% under low risk and 23% very low risk.

On the basis of above results, it is suggested that areas falling under the category of very high and high risk or hazard should be avoided or if unavoidable, should be used with necessary precautionary measures in advance. The moderate hazard or risk zones can be used with appropriate remedial measures at the time of construction. However, low and very low hazard or risk zones are recommended for any landuse activity in the area but prior local investigations may be done at these sites, if required.

MITIGATION MEASURES

Landslide hazard mitigation consists of those activities that reduce the likelihood of occurrence of damaging landslides and minimize the effects of landslides that do occur. Since most of the landslides in Dharamsala township are triggered by human activities and are directly related to construction activities, appropriate grading codes can significantly decrease landslide losses in Dharamsala area. The best opportunity for reducing landslide hazards are found in landuse planning and the administration and enforcement of building codes.

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The vulnerability of people to landslide hazard or anyother natural event is determined by the extreme events, the proximity of people to those occurrences, and the degree to which the people are prepared to cope with these extremes of nature. Effectiveness of landslide mitigation in Dharamsala township or any other area is generally tied to the ability and determination of local officials to apply the mitigation techniques in hazardous area. To cope up with the existing problem some important remedial measures have been listed below, although for each slide zone, separate remedial measures have been discussed in detail. The inventory of the slide zone is given in Table 2 and all possible measures to control / prevent slope failures are also listed. Any mitigation measure requires cooperation from local inhabitants, otherwise it may not be possible for the government body to mitigate any hazard. So community participation is an important component in any mitigation measures.

- **First and foremost action which needs special attention is laying down of proper sewerage disposal system in Mcleodganj area, Army Cantt area, Tibetan Library complex area, Dharamsala Township including Mant Panchayat without which it is not possible to achieve anything by taking any other measures.**
- **Adequate and well-planned drainage is the basic requirement as a long-term measure. It should consist of hill side catch water drains and culverts both along and across the contour lines.**
- Local residents need to channelize their daily water disposal in a proper way so that it should not seep into the body of the slide zone or bare slopes.
- Special care is needed to stop construction on NE face of Mcleodganj and in the Librarian complex area
- There is an urgent need to channelize the wastewater disposal in the Library complex area, Dalai Lama Temple Complex and its surroundings facing the Jogiwara landslide.
- Avoid construction on very high hazard zones and very high risk zones. See fig.
- All natural drains need to be cleared before every monsoon season because choking of drains creates pools/ponds thus increases infiltration into the subsurface.
- Aforestation of the area using site specific species and fast growing plants in the crown portion of Tikka Gamru slide zone. Station HQ slide zone, Jogiwara slide zone, Mcleodganj NE hill slopes etc. to mitigate the unstability of the slope. This will also improve the aesthetic beauty and environment of the area.

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- Along the high seepage zones water should be drained out through inserting perforated pipes. This will increase the stability of hill slope.
- The water standing on ditch on the uphill direction should be drained out.
- Avoid constructions over steep and distressed hill slopes
- Avoid further construction in the Mcleodganj hill and in Mcleodganj town area.
- There should be restrictions on new construction around active landslide zones.
- All the natural drains in the area should be made of concrete to avoid any infiltration of surface water to the sub soil.
- Construction should be taken up only after detailed studies on the local stability of the terraces and the evaluation of geotechnical parameters

(Dr. A.K. Mahajan)

(Dr. N.S. Virdi)

Date : March 31, 2002

Place : Dehra Dun

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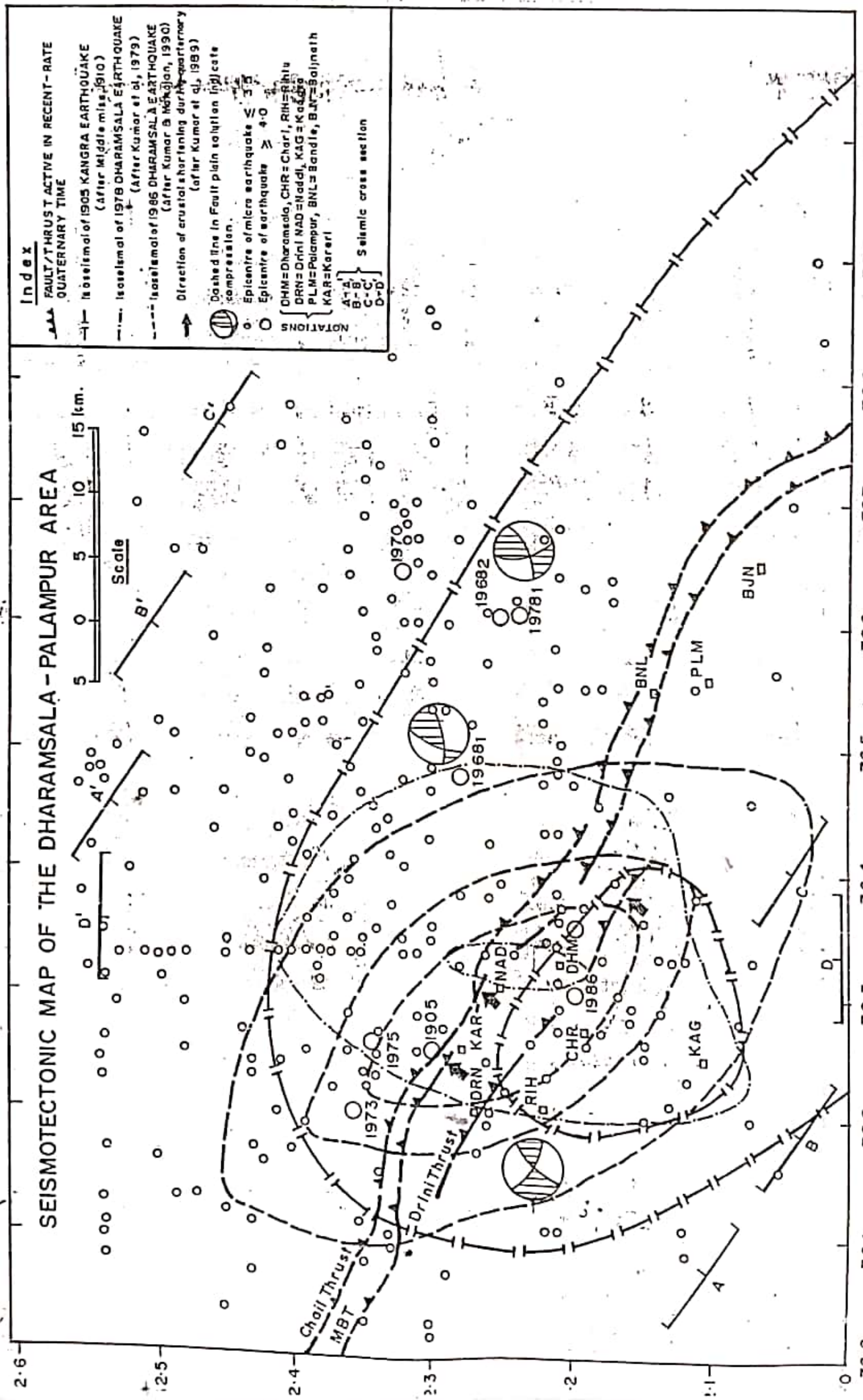

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