परियोजना का नामः- उत्तराखण्ड राज्य में ऑल वेदर रोड़ परियोजना के अंतर्गत जनपद टिहरी गढ़वाल के राष्ट्रीय राजमार्ग–58 के कि0मी0 253.000 से कि0मी0 254.000 के मध्य में सड़क के चौड़ीकरण एंव सुढढीकरण हेतु हॉट मिक्सिंग प्लांट के लिए राष्ट्रीय राजमार्ग लोक निर्माण विभाग श्रीनगर का वन भूमि हस्तान्तरण प्रस्ताव।

प्रारुप–33

परियोजना के निर्माण हेतु भू–वैज्ञानिक की आख्या

प्रमाणित किया जाता हैं कि विषयगत परियोजना के निर्माण हेतु भू–वैज्ञानिक की आख्या संलग्न कर दी गयी है।

अधिशासी अभियन्ता
राष्ट्रीय राजर्मार्ग, लोक निर्माण विभाग
श्रीनगर, उत्तराखण्ड

Table of Contents

1. Introduction

Due to large scale devastation of National Highway network during last year (June 2013) disaster, The Ministry of Road Transport and Highways (MoRTH), Government of India has decided to rehabilitate and upgrade the existing entire National Highways network in the State of Uttarakhand. MoRTH appointed **M/s AECOM Asia Company Limited** in joint venture with **M/s AECOM India Pvt. Limited** as Consultants to carry out the preparation of Detailed Project Report for Rehabilitation and Upgrading to 2 -lane / 2-lane with paved shoulders configuration & strengthening of NH-58 from Km 228.000 (Rishikesh) to Km. 368.000 (Rudraprayag) in the State of Uttarakhand. As the existing road is in the Himalayan terrain, the role of geology is become pivotal. The location of the proposed study corridor is shown in the figure 1 below.

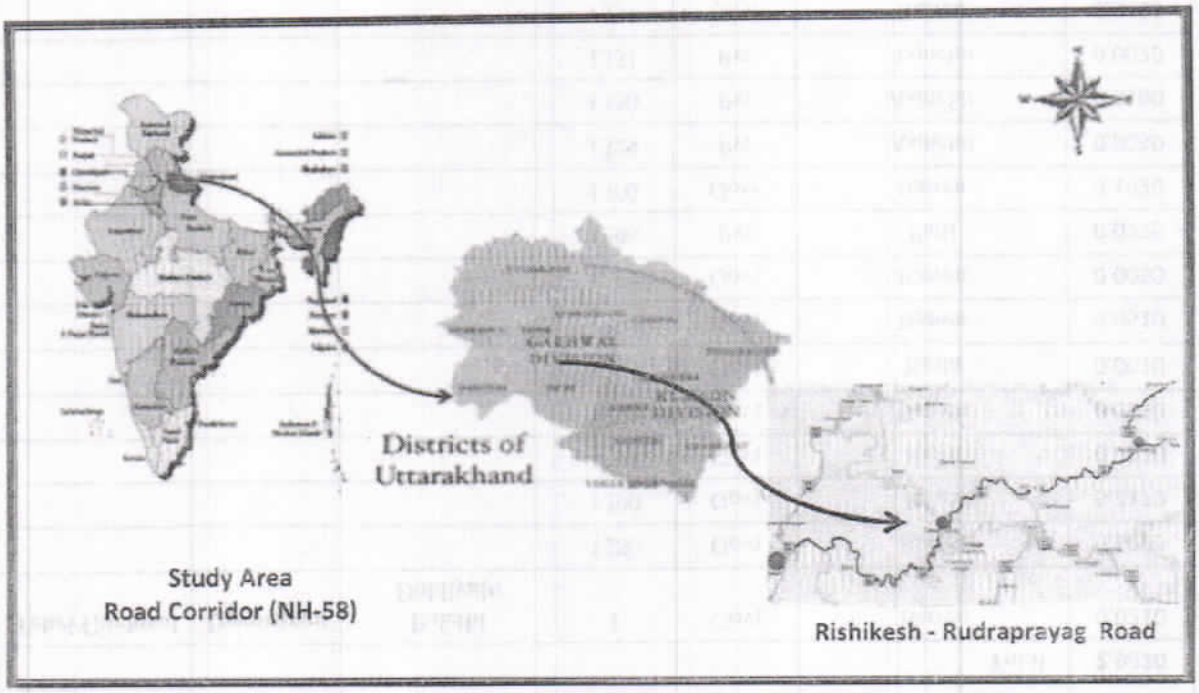


Figure 1: Location Map of the Rishikesh – Rudraprayag Road Project.

2. General Geological Setup

The area represents highly rugged topography characterized by moderate to steep slopes that are intervened by narrow valleys. The topography of the region appears to be controlled by the structural and lithological factors. The area thus exhibits high relative relief. Presence of overburden on steep slopes and high precipitation make this area prone to landslides.

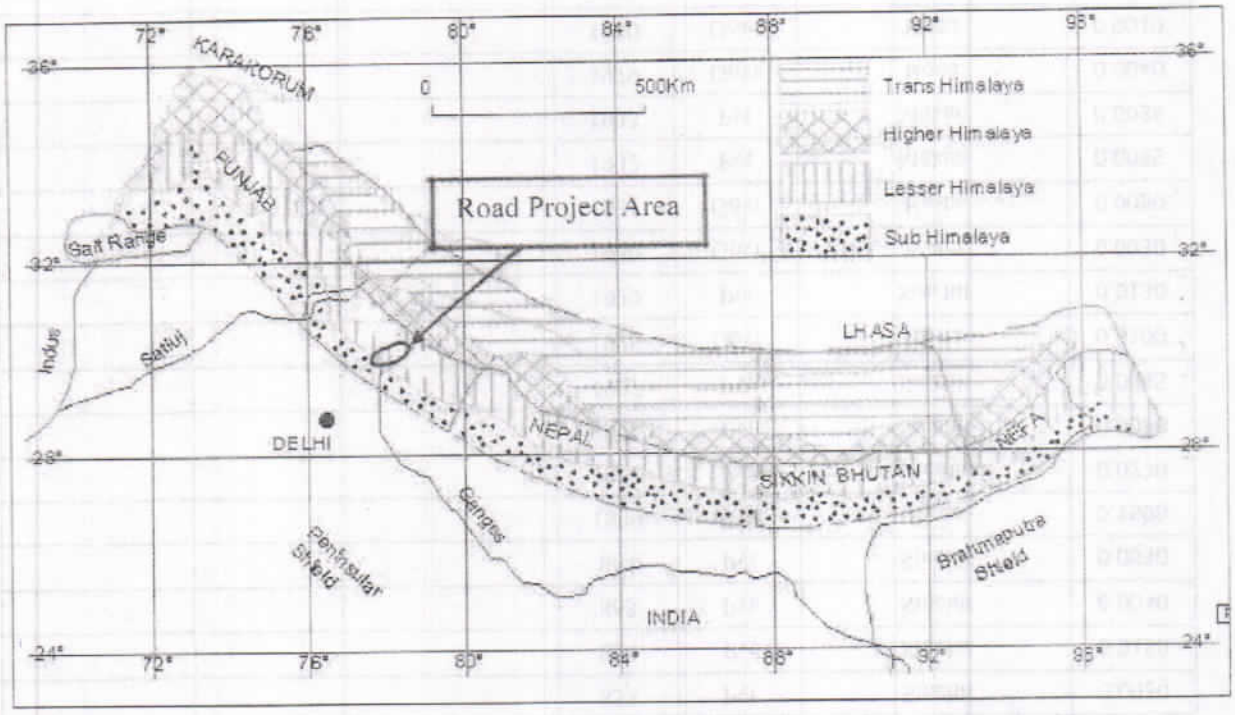


Figure 2: Longitudinal views of Himalayas showing the study area.

In general, Garhwal Himalaya is well known for its fragile landscape and frequent geological hazards, among which landslides are the regular threats over this region. The present road project is located mainly in Lesser Himalayas. This road corridor is passing through a highly rugged terrain of the upper Ganga river valley up to Devprayag and lower Alkananda river valley up to Rudraprayag of Uttarakhand. The area is suffering from frequent landslides especially during every monsoon season.

3. Geomorphology & Drainage System

Physiographically the area is within the Lesser Himalayan zone having elevations ranging from 500-2200M. However, according to the transverse regional divisions across the mountain chains of the Himalayas, the project area is located within the Garhwal Himalaya. The generalized topographical views are shown in the figure 3.

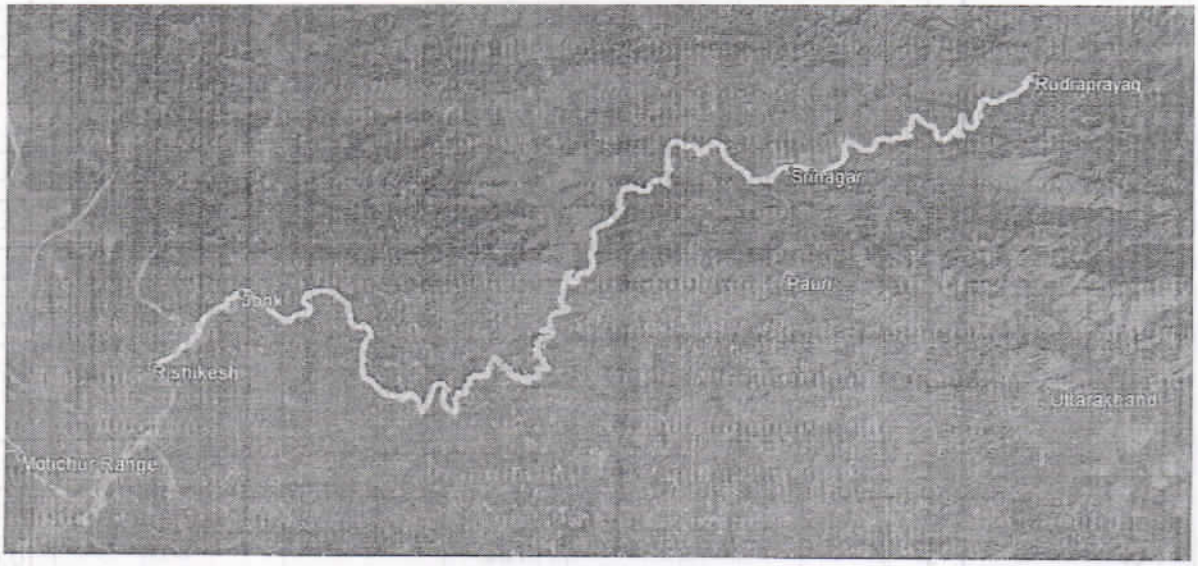


Figure 3: A panoramic view of the topography and the drainage system of the River Ganga and Alkananda with reference to the Rishikesh – Rudraprayag Road corridor.

The Garhwal Region which has been a well-known abode for saints & peers is geologically very fascinating as well. H.B. Medlicott (1864) was first to study the stratigraphy of Kumaon region which was followed by works of R.D. Oldham (1889, 1988) & Midlemiss (1855-1890). In the late 1930's the works of J.B.Auden, A. Hein & A. Gansser have been published, whereas during 1960s & 1970s a lot of detailed work was carried out in the area. Prof. K.S.Valdiya of Kumaon University undertook the work of regional co-relation and his book on the subject is well known among geologists.

It is remarkable that dissected topography with narrow valleys and escarpments, concave hill tops with extremities in elevation being 400-500M in river bed to 2000M at hill tops characterizes the Lesser Himalaya in this region. The Holy & renowned river Alaknanda rises at Satopanth Glacier in Uttarakhand. One of the sources of the river is also Satopanth triangular lake which is at a height of 4402M. The Alaknanda passes through western boulders of Pauri Garhwal district separating it from Tehri Garhwal district. It passes through Vishnuprayag where it is joined by

Dhauliganga river & further downstream Badrinath temple, natural spring Tapth Kund are also on the banks of Alaknanda. At Rudraprayag it is joined by Mandakini River. The origin of river Alaknanda is also known as Alkapuri whereas after flowing for about 200 km the river merges with Bhagirathi at Devprayag to form mighty Ganges River. In general, the river follows SW direction throughout its length barring local variations. The Alaknanda valley between Srinagar (Garhwal) and Devprayag is wider at some places having deposited a number of flatter terraces especially near Kirti nagar – Maletha area in these areas, the river also flows in big loops. However, beyond Muchhali the river follows straighter course in SW & South direction upto Devprayag.

The mighty Ganga is formed at Devprayag by the confluence of Holy Rivers Alaknanda & Bhagirathi. The holy river flows for about 10km in southerly direction downstream of Devprayag up to confluence in the Nayar river. Thereafter it takes a swing towards the west and flows in big loops & curves towards Rishikesh. Further downstream its follow more or less straight path with little meanders.

4. Regional Geology

The entire study area from Rishikesh to Rudraprayag via Devprayag, is having a very complex geology, which varies from outer lesser Himalayas to inner Lesser Himalayas. The entire stretch is showing variation in rock type of Proterozoic to Cambrian meta-sediments. These meta-sediments intersects by faults and thrusts at many places. The bed rock is also suffered multi-phase of folding at places. The regional geological map (source GSI) showing the complexities and rock type variation as shown in the figure 4.

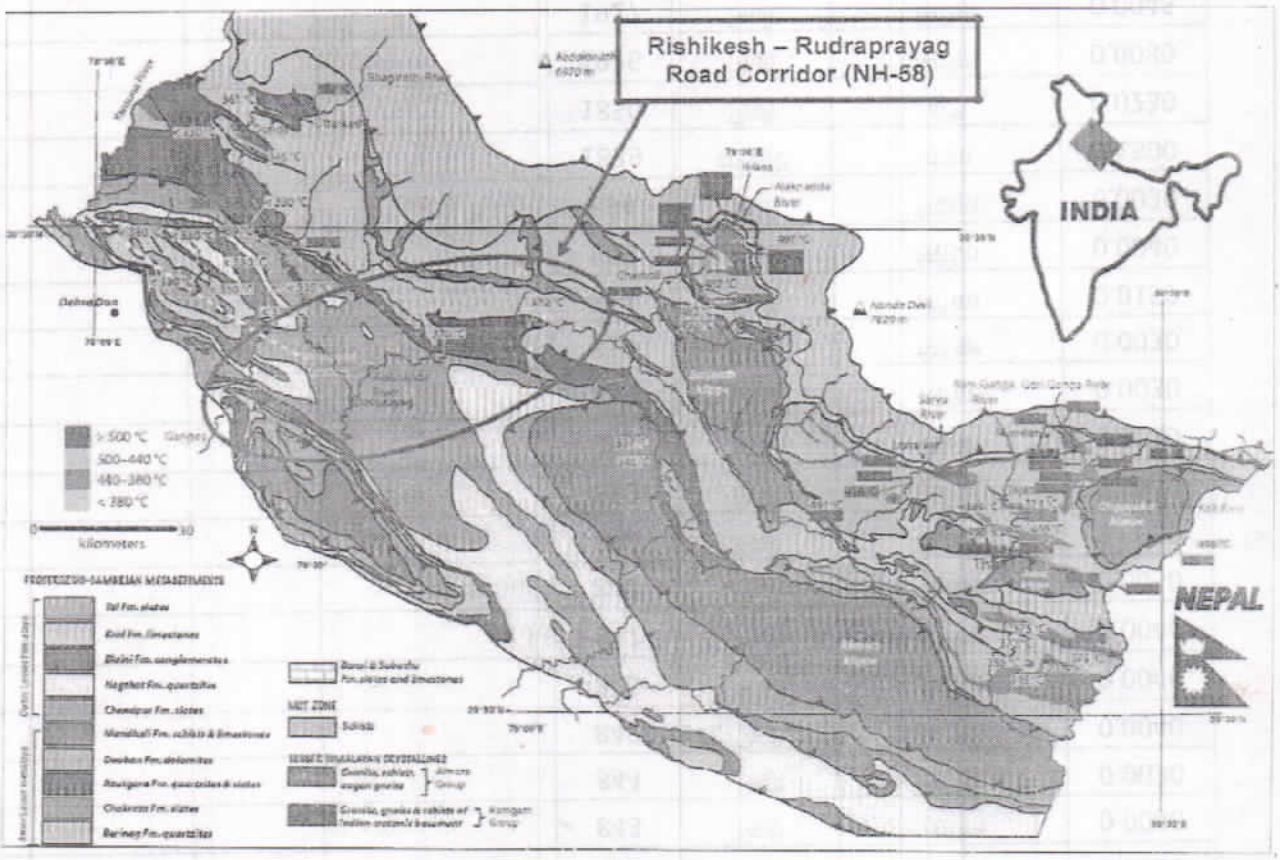


Figure 4: Regional Geological Map of Uttarakhand showing the Rishikesh - Rudraprayag Road

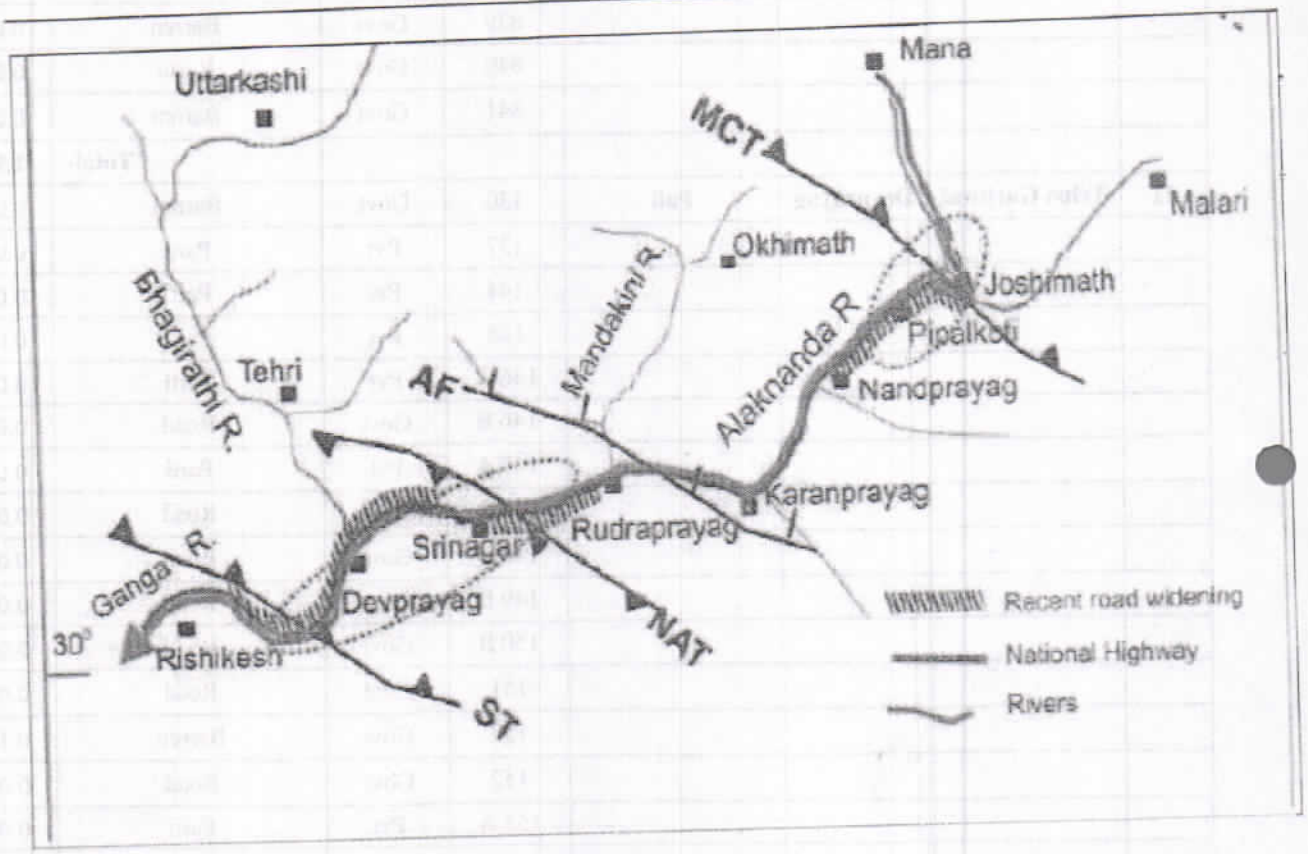


Figure 5: Map of the Upper Ganga and Alaknanda valley showing prominent faults/ Trusts. These are MCT - Main Central Thrust; AF- Alaknanda Fault; NAT - North Almora Thrust; ST - Saknidhar Thrust.

The stratigraphy succession (after GSI) of the area is given below:

Group	Formation	Lithology	Age
Alluvium (Undifferentiated)		Boulder, cobble, pebble, sand, and clay. Talus fan deposits and landslide material.	Pleistocene to Holocene
	Boulder slate	Quartzite, sandstone, sandy limestone, slate and pebble beds.	Lower Permian
Undifferentiated Tal		Quartzite, purple sandstone, with inter bands of shale and siltstone.	Cambrian
Undifferentiated Krol	Krol	Bluish grey dolomite limestone, Calcareous shale limestone-shale intercalation.	Upper Proterozoic
Undifferentiated Baliana		Purple and green shales, bleached shales with boulder beds.	
	Chandpur	Light and dark grey phyllite with thin interbands of light grey and purple sandstone, purple coloured stripped sandstone and siltstone and siltstone interbands.	Lower Proterozoic
Jaunsar	Mandhali	Purple coloured sandstone, siltstone grey phyllite and shale-sandstone interbands with occasional diamictite bands.	

5. Seismicity

The regional geological setup of area as shown in above, it is clear that the road corridor is in Outer and Inner lesser Himalayas. According to the Seismo-tectonic Atlas of G.S.I. (2000), the corridor lies within older folded sequence over printed by Himalayan fold-thrust movement. The locations of important thrusts / faults are within the vicinity of the corridor and at places it intersects also. As per seismic zonic map of India, the area lies in Zone IV, very close to Zone-V.

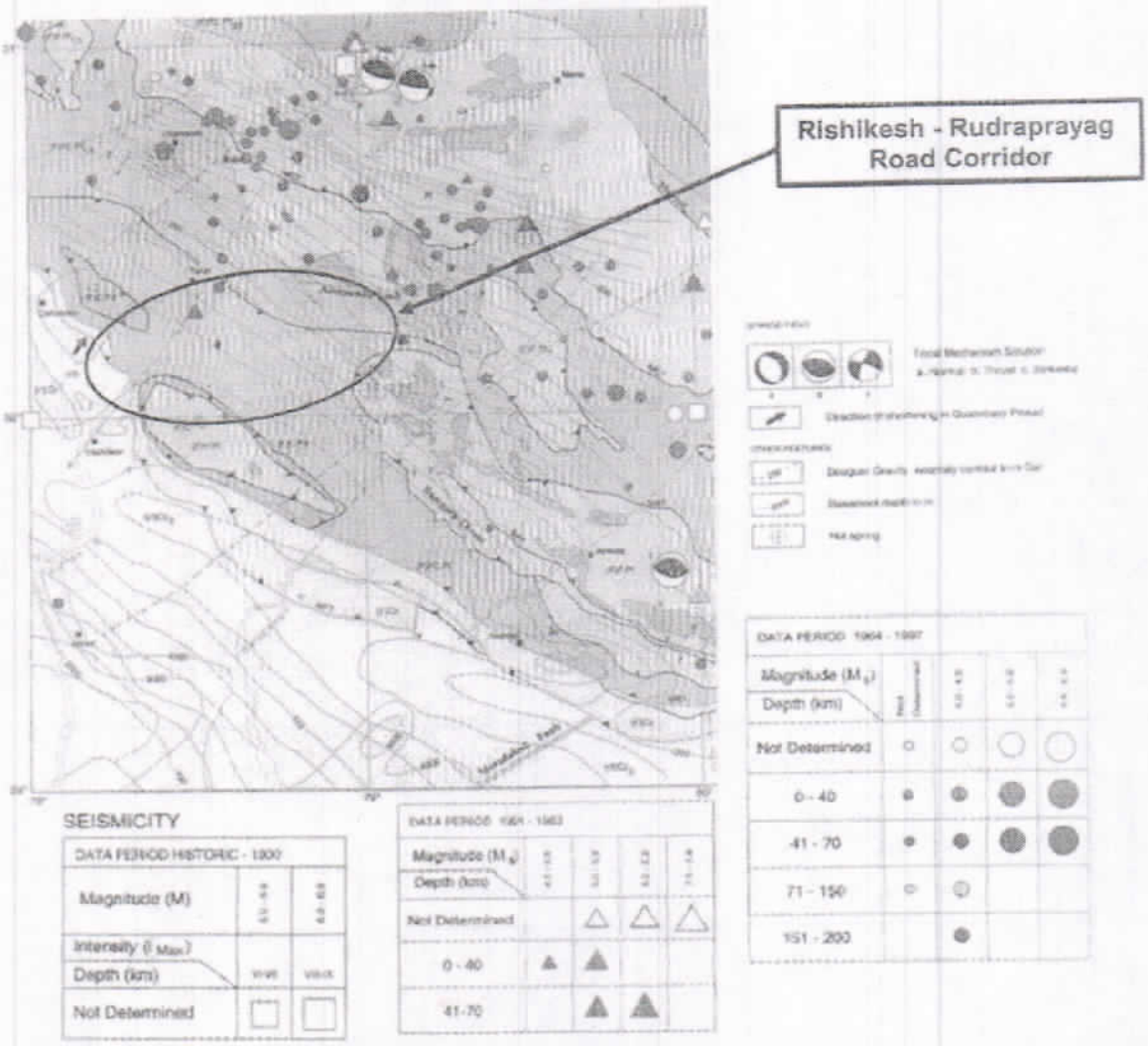


Figure 6: Siesmo-techtonic Map of the proposed study corridor with reference to the past earthquake historical data

In the lesser Himalaya, the geological formations have suffered extensive tectonic movement and the rock formations were subjected to displacement from their original place of deposition. This transportation was carried due to large scale thrusting of various geological formations due to intensive operative compressional tectonic activity in geological past resulting in numerous nappe structures. The Krol belt underlying the undifferentiated Tal group is represented by two tectonic units, one Krol thrust in the south & Tons thrust in the north. The Nayar and Aglar Faults of the southern Pauri and southern Tehri too have developed characteristics due to the above folding. The Tal Group has a thrusted contact with the Bijni formation, known as the Bijni Thrust. It is apparent from the above, that the region under review lies in the active seismic zone and epicentres of some major earthquakes had been located in the region, a few of which had caused damage to property and resulted in loss of lives. The occurrence of earthquakes in the region is attributed to various geological and tectonic features, such as the Main Boundary Thrust (MBT), Main Central Thrust (MCT), North Almora Thrust and some other transverse faults in the Himalayas. Seismotectonic studies reveal that most of the events that occurred in the region are clustered in the vicinity of the surface trace of the Main Central Thrust (MCT).

Notable of the above occurrences are the Uttarkashi earthquake of 19th October, 1991 and the Chamoli – Rudraprayag earthquake of 28-29th March 1999. The maximum seismic intensity close to the epicenter was VIII, in the latter case.

6. Project Geology

The study area has been traversed and evaluated in view of the widening of the existing highways to 2 lane with paved shoulder Highways. The stability of the cut slope, stability of the existing road from the toe scouring by the river, subsidence of the road, new proposed bridge piers foundations are the major concern and issues which has been evaluated with reference to the geological conditions of the area. The observations are mentioned in the below paragraphs with the recommendations to handle the problems wherever it foresee. For convenience of the study it entire study corridor is divided into many sections, which is described as follows:

(1) Rishikesh – Byasi Section

The existing road corridor in between Rishikesh – Byasi is running almost parallel to the mighty river Ganga. The bed rock in this stretch is mainly meta-sediments of Proterozoic – Cambrian age. The part of this outer lesser Himalayas is mainly composed of Quartzites of Nagthat formation, Conglomerates of Blaini formation, Limestone of Krol formation and slates of Tal formation. The prominent regional feature in this section is a Bijni thrust running almost east-west and dipping toward south. This thrust is also identified and marked in the regional geological map of this region (refer figure 4 & 5). The impact of the thrust where it crosses the hill slope along the road is evidenced at site.

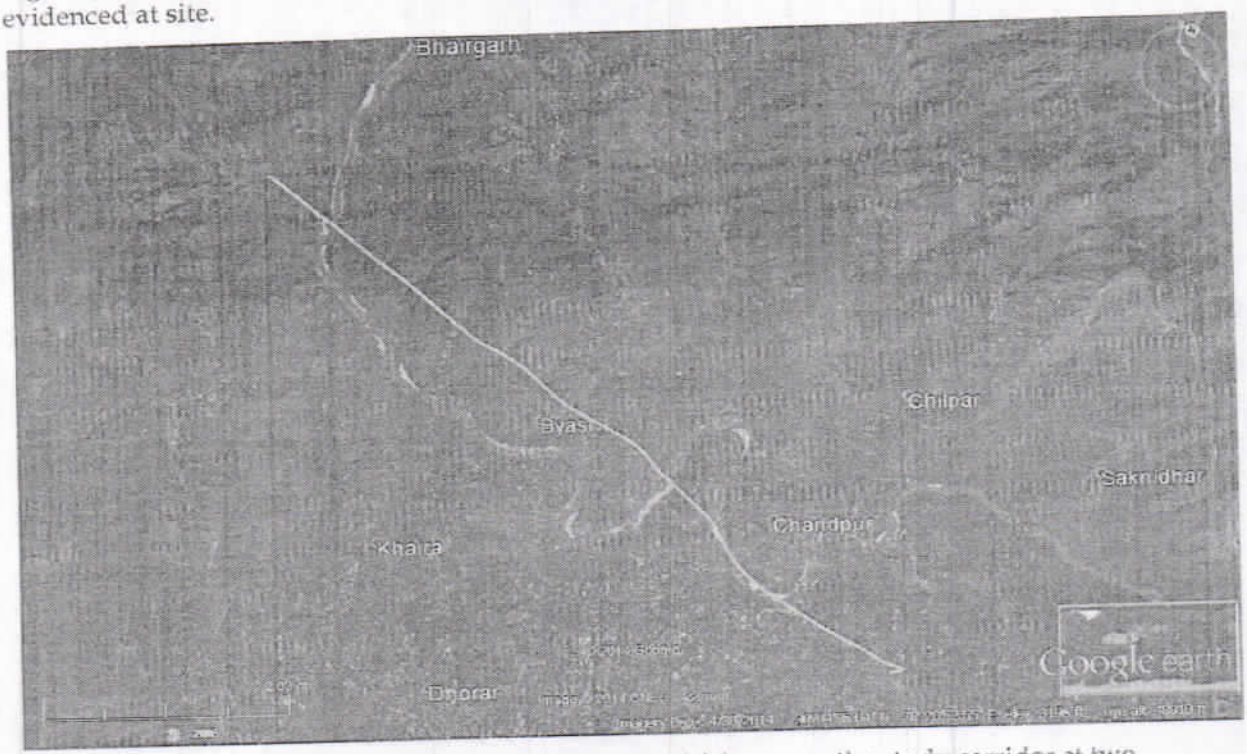


Figure 7: Google map showing the Bijni Thrust, which crosses the study corridor at two locations; one at downstream of Byasi and other is up stream of Byasi near Kaudiyali

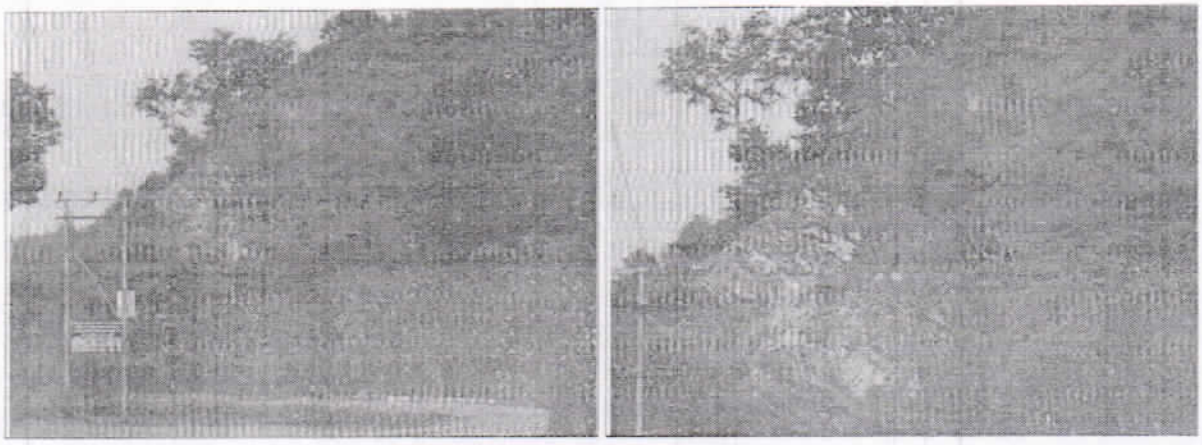
The study corridor start from Rishikesh where the most part of the city area is situated on the river fan deposits, which is mainly composed of unconsolidated to semi-consolidated materials. The riverine fan deposits are having composition of fine – medium to coarse grained sand with pebbles, cobbles and boulders. The usual characteristics of the fan deposits are their layering which depicts the seasonal depositional history. The existing road in this section is also founded on the same material. The part of road in this stretch is founded on the riverine terrace deposits and at places on the bed rock covered by overlain slope wash material. The back cut slope along the road is completely covered by houses, buildings and slope wash material.

Further upstream the settlement of Tapovan is also founded on huge fan deposits of the seasonal nalla. The formational history of these deposits is the deposition of huge quantity of nalla debris came with water in the heavy rains / cloud burst situation. This debris obstructs the river Ganga flow and force to scour the left bank of the river and the river course taking a small curve. These entire settlements are also on the unconsolidated / semi-consolidated debris deposit. The existing road is also crossing on the same foundation.

Further upstream most of the area of existing road section is covered by slope wash material. The slope wash material is composed of angular to sub-angular rock fragments of bed rock with medium to coarse grained sandy matrix. The slope wash is cover covered by vegetation at most of the places. At places the riverine terrace material also rest long the hill slope which including the entire Byasi area.

The hill slope is seems to be stable in most of the places in further upstream in this study corridor except few location shows the slope failure and land slide problems. Each case is discussed here one by one in below paragraphs.

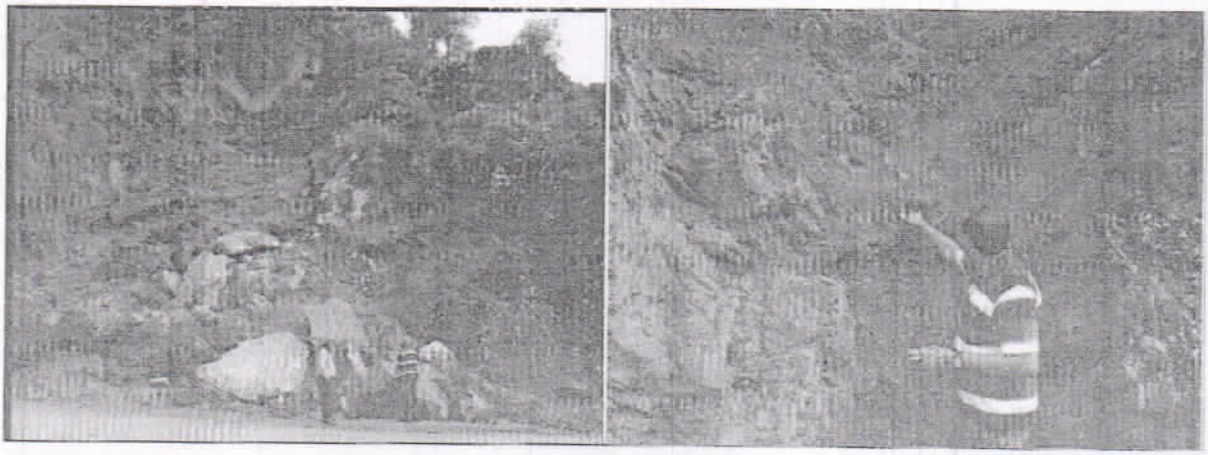
Slide No.1 at about Ch. 234.500



The above slide is an old rock slide not very significant threat to the road widening activity. The bed rock is bedding plane having attitude of N/65^0- 70^0. The bed rock is thinly bedded and local warping is also observed on the plane of failure. At upper reaches there are few meters of slope wash rest on the bed rock. The mechanism seems to be failure along two set of discontinuity in the

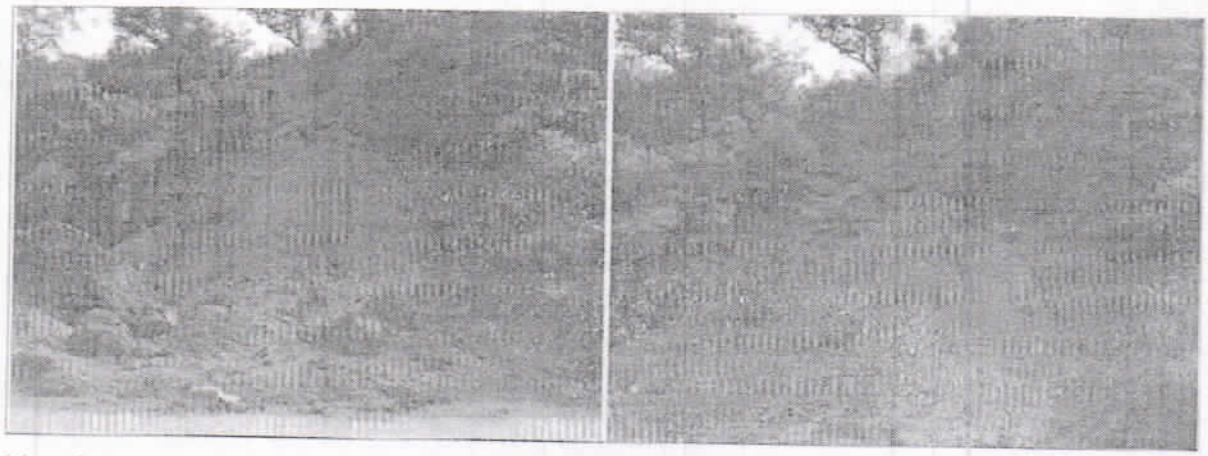
bed rock making a wedge. Thus it is suggested that while cutting of the hill slope during widening toe should be necessarily protected.

Slide No. 2 at about Ch.234.600



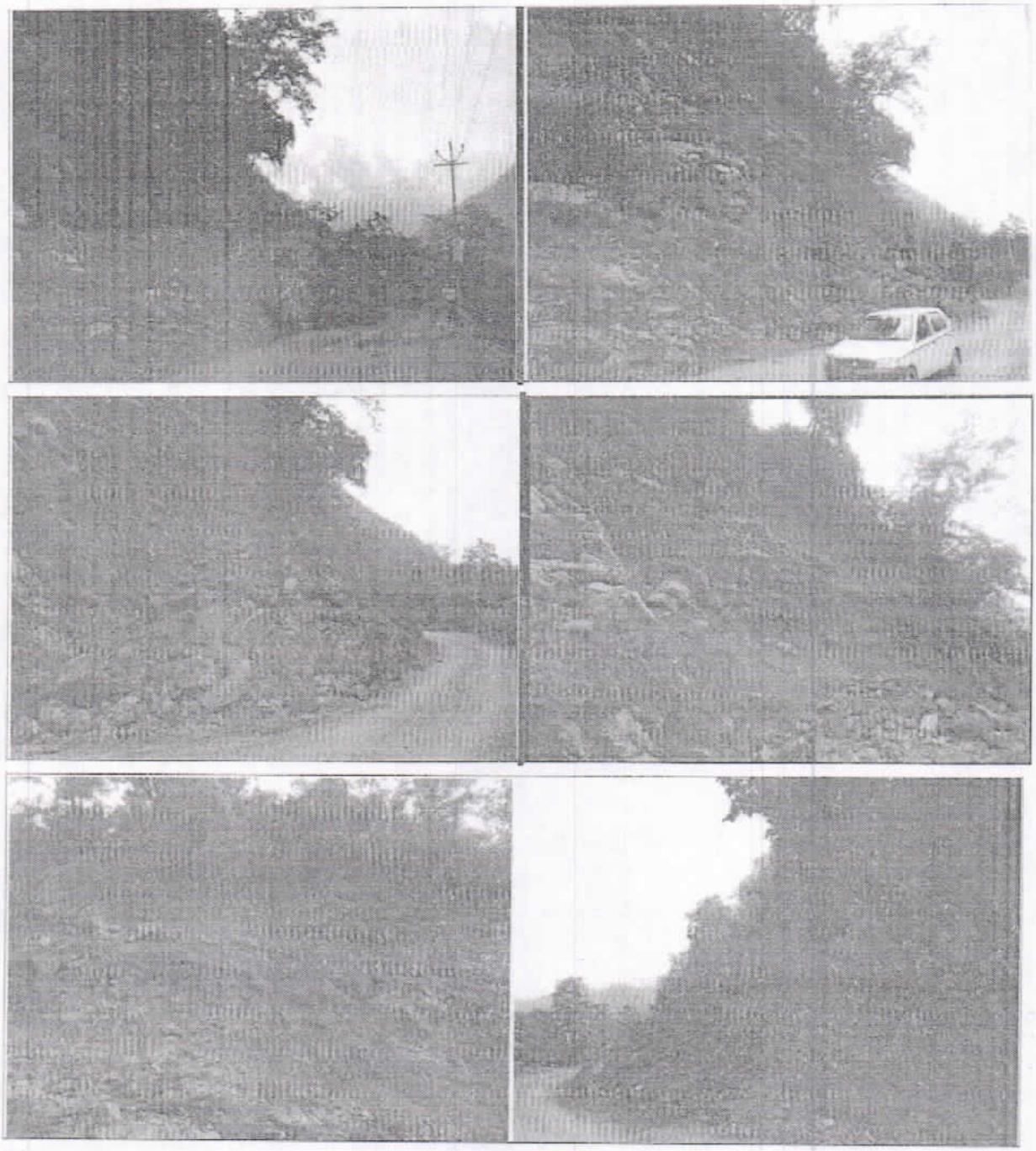
The above Slide is a typical wedge failure in the bed rock which is mainly limestone. A closer view shows that the limestone suffers high grade of weathering in the exposed surface. This is not very significant as the natural hill slope in this case is almost maintaining the angle of repose. However, the degree of weathering is very high. Thus it is suggested the toe support measure should be taken while widening.

Slide No. 3 at about Ch.235.100



The above area is highly weathered zone where bed rock is completely disintegrated due to chemical weathering. This slide zone is not seems to be any significant threat to during widening of road.

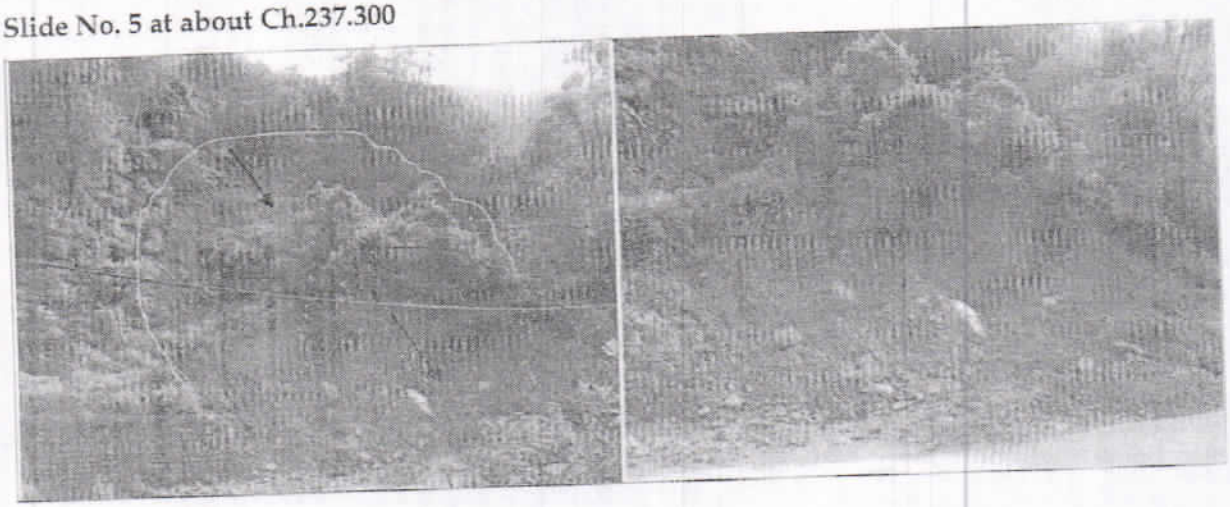
Slide No. 4 at about Ch.236.900



This rock slide occurs at Ch. 236.900m. The bed rock is highly jointed and fractured quartzite. The bed rock is thinly bedded and is having prominent discontinuities of $070^0/65^0$-70^0; $150^0/80^0$-85^0

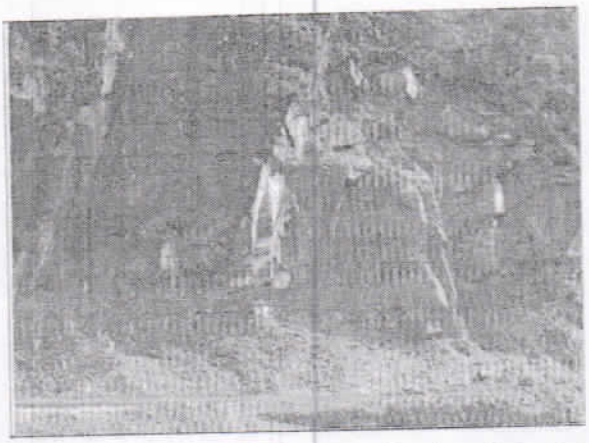
and $290^0/35^0$-40^0. This collapse occurs due to wedge failure in the bed rock. During widening of the road the toe of the slope should be supported to prevent further aggression of the slope failure.

Slide No. 5 at about Ch.237.300



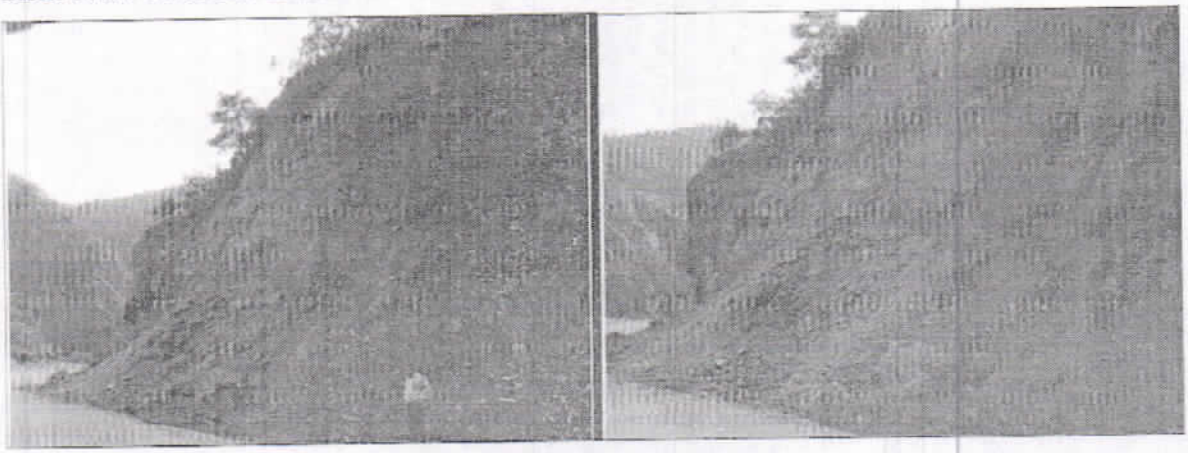
This is an old slide in area covered by slopewash material. The slided material is mainly composed of medium to corase grained sand and silts with angular to sub-angular small fragments of bed rock material. It is not very significant and disturbing during widening and slope cuting. However toe support to also required to further initiation of slide during widening.

Slide No. 6 at about Ch.239.000



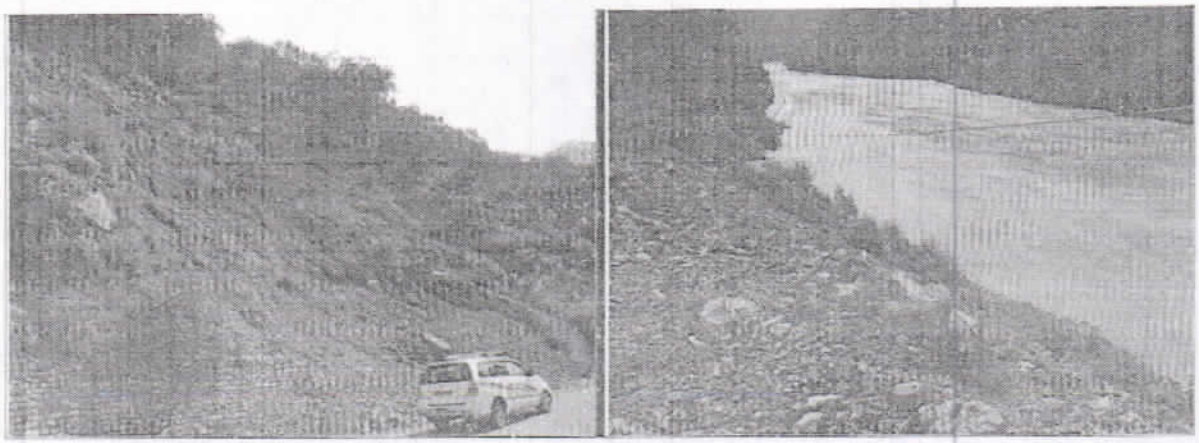
The above slide zone is a rock slide in massive hard quartzites. The failure mechanism is typical case of wedge failure govern by two prominent set of discontinuities which are $110^0/75^0$-80^0 and $225^0/70^0$-75^0. While cuting this bed rock during widening of road, the toe support measures should be provided immediately after excavation.

Slide No. 7 at about Ch.241.700



The above slide area is maily rock slide in highly weathered fractured rock mass. Rock mass is slided from discontinuities which is filled by clayey material. It is basically a type of planner failure which occurs due to rain water that dilate the undulating sub-vertical planer suface. Not very significant threat to road during widening. However basical toe support measures should be taken care.

Slide No. 8 at about Ch.244.800



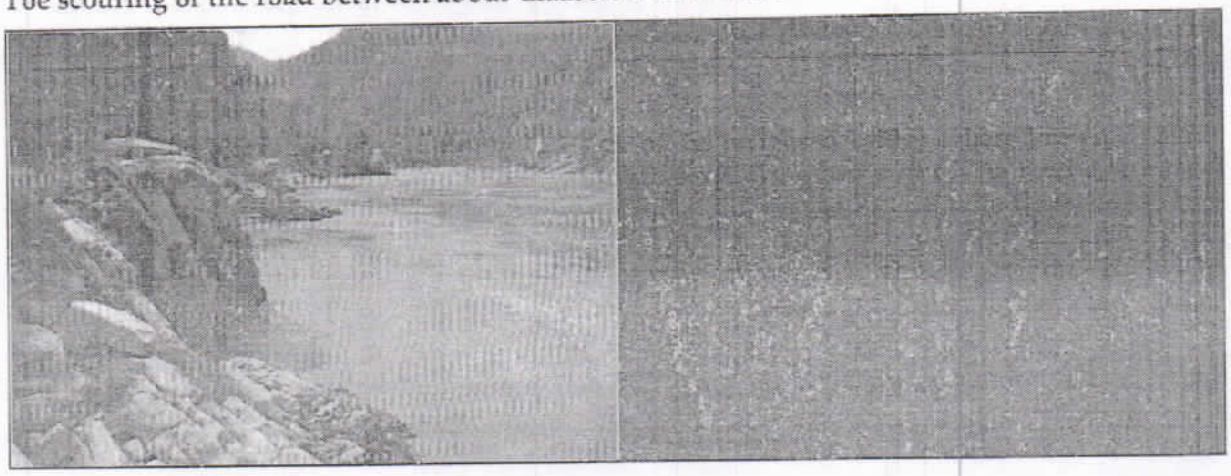
The above slide is the slide in slope wash material which is mainly composed of medium to coarse grained sand and silts with small fragments of angular to sub-angular rock material. The failure is triggered due to rain water that lubricates the pervious slope wash material rested on the hill slope.

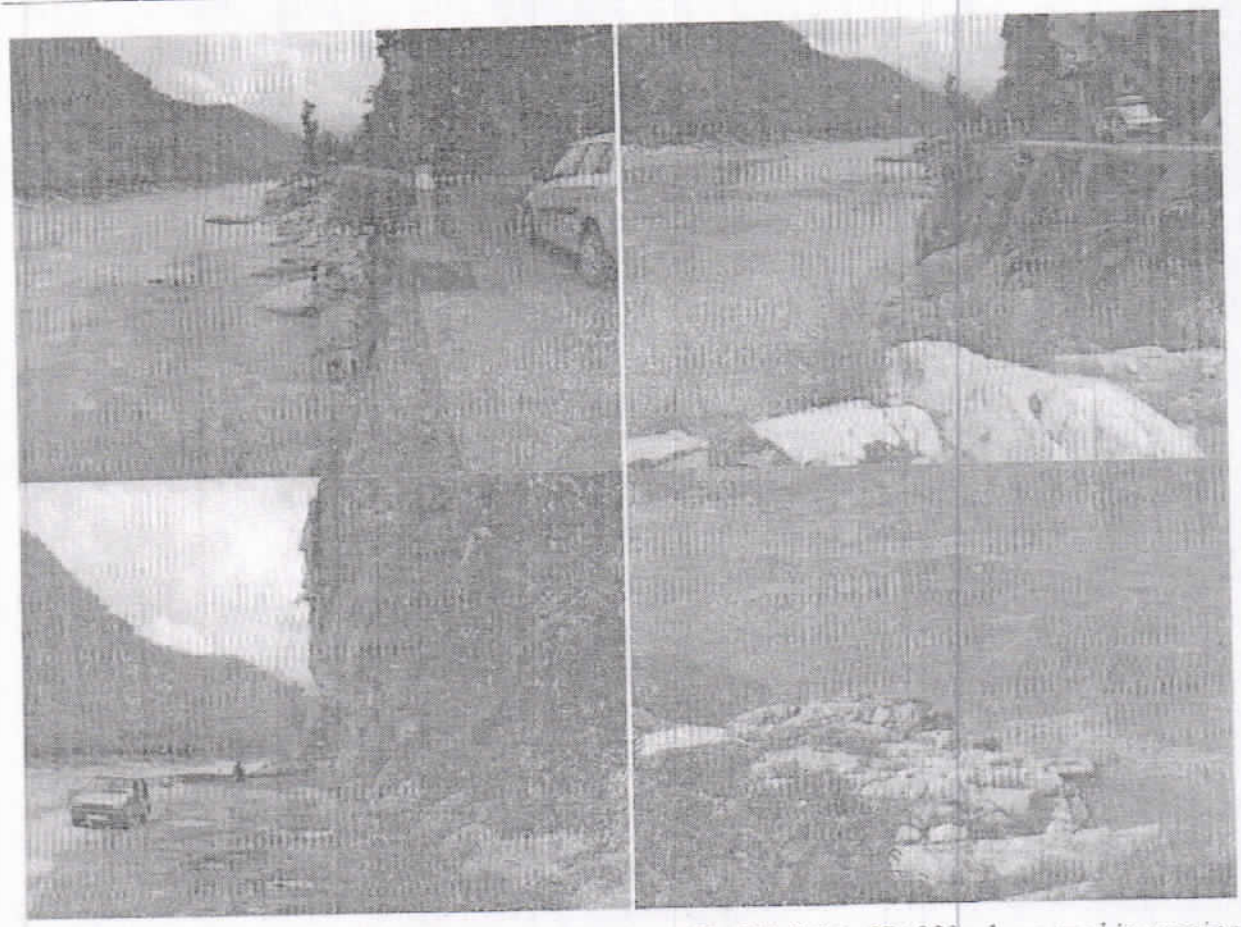
Thus it is advisable to protect the toe of such slope during cutting of the existing slope for widening.

Proposed Bridge in Minor Realignment at Ch. 250.650 to 250.800m

The area in the pictures is the upstream pier side of the proposed bridge where brown coloured phyllites are exposed in the bottom of the road. However the outer part of the road at corner is over hang on the bed rock. These foundation rocks suffer scouring by the nalla flow during high flood time. Above the road the hill slope is covered by slope wash material. Similarly the downstream side entire area is covered by slope wash material and vegetation. Thus it is suggested that during construction of the bridge both the piers should founded on the firm bed rock and its load bearing capacity has to be ascertained.

Toe scouring of the road between about Ch.253.000 to 254.300





The area showing in the above pictures is in between Ch. 253.000 to 254.300 where road is running almost parallel to the river flow. The bed rock is exposed along the hill slope which is almost vertical and at places over hanging above the road. The bed rock is massive quartzite, which is traversed by four set of joints. The prominent discontinuities are $215^0/55^0$(S-1), $030^0/35^0$(S-2), $300^0/15^0$(S-3) and $320^0/85^0$(S-4). The river is flowing few meters below the existing road. At many places river scouring action active on the exposed rock below the road which create a threat for stability of the road in future. Another point of concern is the widening of road in this rocky stretch. Cutting of hill slope in this stretch is a herculean task simultaneously making any structures towards river side is also a cumbersome job. However, as the rock exposed in the bottom just at river level below the road, there is a possibility to construct wall which will rest on the rocky foundation. This concrete wall will restrict the river scouring at toe furthermore and on the hill side of the wall after filling, road can be widened. Keep in view of the above situation it is advisable that during designing of any of such structure, precautions should be taken and design it keeping in view of heavy water discharge in future.

Rest of the areas are seems to be stable and not anticipated any major threat during excavation and lateral cutting of the road. However, general precautions should be taken throughout the stretch of this section.

(2) Byasi – Devprayag Section

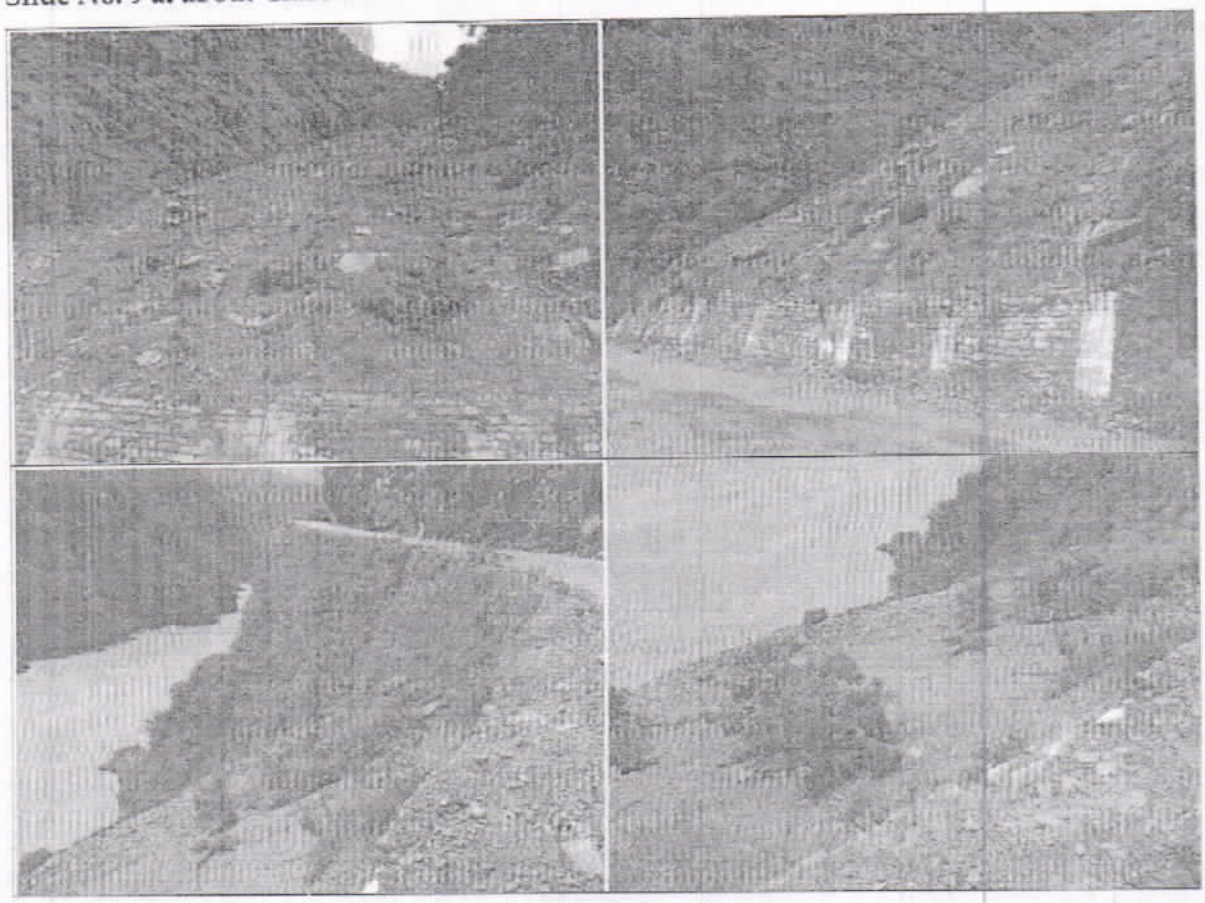
The holy river Ganga flows for about 10km in southerly direction downstream of Devprayag up to confluence in the Nayar river. Thereafter it takes a swing towards the west and flows in big loops & curves towards Rishikesh. The present section of the study corridor is in between Byasi to Bachedikhal section where overlooks village Kaudiyala and is located in one of the big loops while the river is negotiating through undifferentiated Tal sequence.

As per the studies of Geological Survey of India a major part of this area is manifested by Jaunsar Group of rocks of early Neo-Proterozoic age. The area falls in toposheet no. 53J/12 which has been covered in Regional Geological Map of GSI. In the SW corner of the sheet the northern limb of synform comprising of Baliana Group, Krol & Tal sequence is present. Regional Geology Map for project area as reproduced from GSI map is presented at Figure 4.

From about 3 to 4 km upstream of Devprayag to about 10km downstream, the Mandhali formation belonging to Jaunsar group is present. In the downstream of Devprayag, after about 10km, the rocks of undifferentiated Baliana Group overlie Mandhalies by an unconformable contact. Subsequently, Krol & Tal sequences are present having average surface manifestation of 1km each across the strike. Finally, the rocks identified as Bijni formation having purple greenish grey and white quartzite with subordinate bands of argillite occur as thrust over Blaini-Krol-Tal sequence. They are considered equivalent to Mandhali Formation. Further, the Amri Formation having tectonic contact with Bijni Formation has been correlated with Chandpur Formation which is represented by argillite with subordinate bands of flaggy and schistose quartz-arenite. Immediately upstream of Bijni thrust, river Ganga flows in two big loops in undifferentiated Tal sequence. Quaternary alluvium is present at many places along the three major river valleys which are shown as undifferentiated alluvium.

The rocks of Baliana Group, Krol & Tal sequence show WNW-ESE strike extension with southerly dip, and occur as northern limb of a synform. The rocks of Bijni nappe have a thrust contact with Tal sequence which is known as Bijni Thrust. Another thrust named as Amri Thrust separates Amri formation (occurring in core of synform) which overrides Bijni. According to Regional Geological Map, the Bijni Thrust is passing in between Byasi and kaudiyala. However, it is dipping towards south.

Slide No. 9 at about Ch.264.100



The above slide is mainly along the topographic depression which followed by the seasonal nalla. Nalla debris is resting throughout the course of this depression from top to the river level. Thus it is suggested that this seasonal water flow should be detoured by any over bridge and synonymous structures. So that water and its debris material in case of rainy season can move beneath the road and movement will not restrict in any case.

7. Conclusion and recommendations

The study corridor from Rishikesh to Rudraprayag crossed various type of rock having different degree of weathering and fracturation. Significant area is having very high degree of weathered and fractured rock mass. Two very prominent regional thrust is crossing the study area and gives significant impact on the stability of the highway corridor. Study of past historical seismicity also reveal that the area has experienced moderate to high degree of seismicity in past and it might be possible that such type of seismicity also experiences in future too. Keeping in view of the above geological and related seismic conditions, the widening of the highway corridor in this stretch is a challenging work and a scientific approach is to be taken while designing and providing the support measures in the cut slope to prevent future slides.

Thus it is proposed that following steps will be taken care during detail design and construction activity of widening of road.

(a) The road shall be planned particularly in the Rishikesh area above the high food level as in case of any cloud burst of sudden increase of water level; it will not damage or disturbed the Highways movement.
(b) Precautionary measure should be taken in anticipation of any future mass movement during heavy rain fall / cloud burst in this nalla course at Tapovan area.
(c) All the seasonal or perennial streams on the hill slope, which crosses the highway corridor, will be channelized and crossed by drainage structure.
(d) While cutting during widening of the road, the hill slope is cut with stable design slope and toe will be supported immediately after excavation.
(e) In the massive rocky area, the widening activities would be design according to the stability of the overhanging rock mass. In this case box cutting is one of the approaches with supported crown.