

# Landform Evolution and Geomorphometric Analysis of Gaj Khad Watershed, Beas River Basin, Himachal Pradesh, India

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## Abstract

Geomorphometric studies of Gaj watershed of Beas river basin, District- Kangra, Himachal Pradesh reveal accelerating land degradation due to sensitive and fragile geology of the area. The area under study falls in the Frontal Himalayan Zone which is characterized by higher values of erosional intensity that is related to the lithology, geomorphology and tectonic character of the area. In the present paper, an attempt has been made to understand evolution of landforms and degradational processes operating in the study area using morphometric analysis.

**Keywords:** Geomorphometry, Watershed, Tectonic setting, Relief, Stream Order, Erosion intensity, Drainage density

## 1. Introduction

Geomorphometry involves the quantitative analysis of relief/terrain and landforms originated mainly due to various fluvial processes. The morphometric analysis helps to understand the run-off characteristics of a particular area on one hand and the erosional/ corrosional potential of the watershed on the other. Structural and geomorphological features also influence drainage characteristics and erosional patterns of watershed, especially in the Himalayan terrain (Dhar and Dhar, 2002).

Gaj Watershed is a part of Beas river drainage system of Himachal Pradesh and covers about 503Km<sup>2</sup> area. The study area falls under limits of North latitude 32°0' to 32°25' and East longitude 76°0' to 76°25' (Fig. 1). The study area includes part of Dharamshala, Rait, Shahpur, Ranital, Lanj and Nagrota Surian of Kangra district of Himachal Pradesh. Main tributaries of the watershed are Banoi, Chambi, Khauli and Lapiana (Fig. 2). The watershed area shows a great variation in relief being 418m the lowest and 4600m the highest.

Morphometric studies in the field of hydrology were initiated in the 1940s and 1950s. Narula et al. (1997) studied the geomorphometric aspects of various streams in the Kangra valley. The present study of Gaj watershed of Beas river basin furthers the contributions made on watershed studies of Himalayan Frontal zone of district Kangra by Shukla and Verma (1974), Mithal et al. (1974), Lal and Pal (1990), Patwary and Kumar (1992, 93), Lal (1998), Lal et al. (1999) and Dhar et al. (2006).

## 2. Methodology

In order to achieve the goal for objectives undertaken in the study, plotting of detailed geomorphological features and watershed boundary of the area, Survey of India toposheets i.e. 52D/3, 52D/4, 52D/7, 52D/8 (scale 1:50,000) are used. Identification of the broad geological lithounits, structural elements and morphological features were done on the basis of field work and reconnaissance survey. Using the interpretation of the base maps and field survey, identification of environmentally sensitive zones were demarcated. Software tools in ArcGIS-10 and ASTER (DEM) were used in the preparation of watershed boundary, slope-aspect and different thematic maps like drainage density, slope and relief etc.

## 3. Geological and Tectonic setting

Gaj watershed shows a complex and varied lithology and consists of Dhauladhar Granites (Precambrian), Phyllites from Chail Formation (Precambrian), grey Limestones and Dolomite from Dharamkot Formation (Permian to Triassic), purple Sandstone and Shale from Subathu

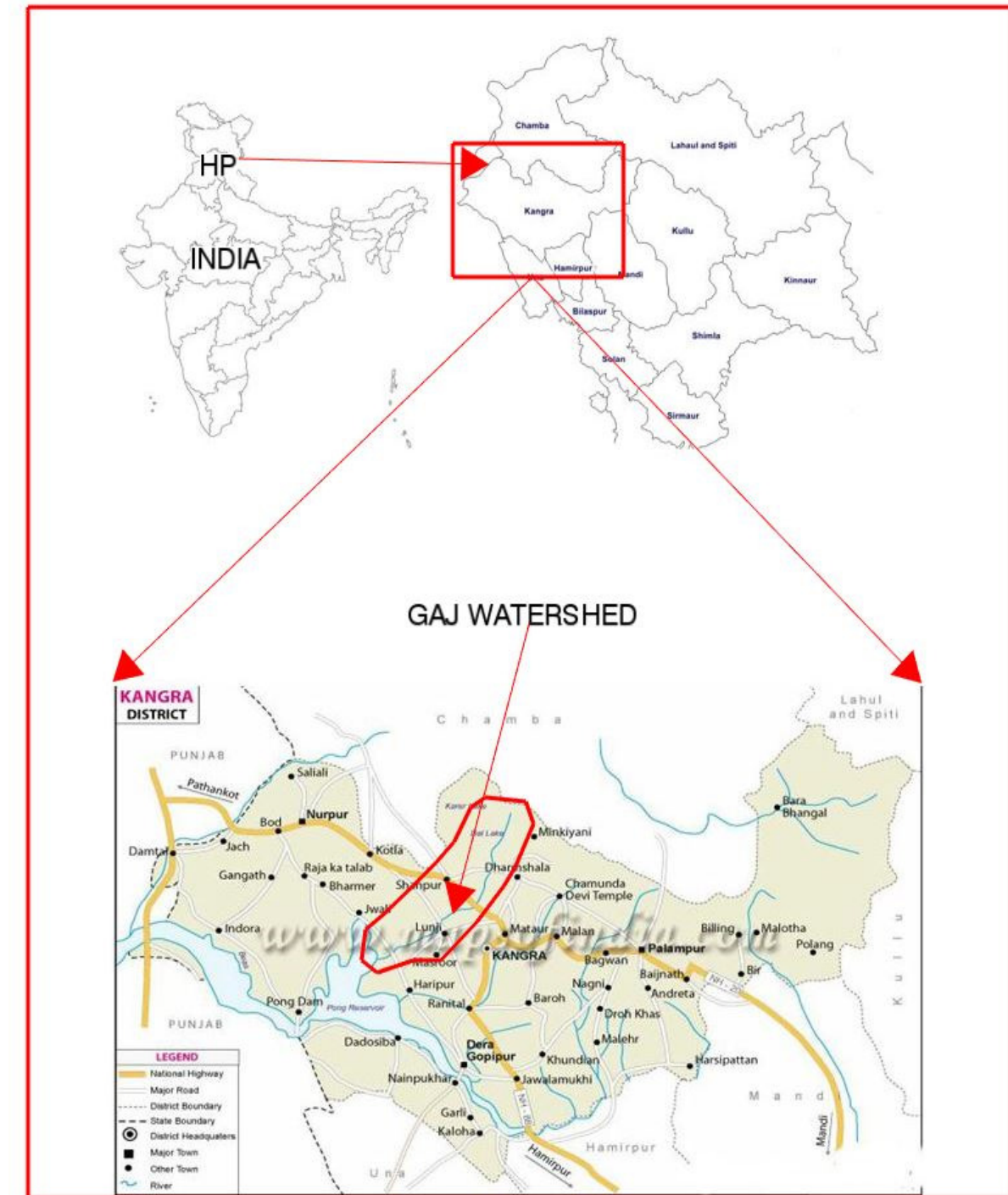


Figure 1: Location map of Gaj watershed

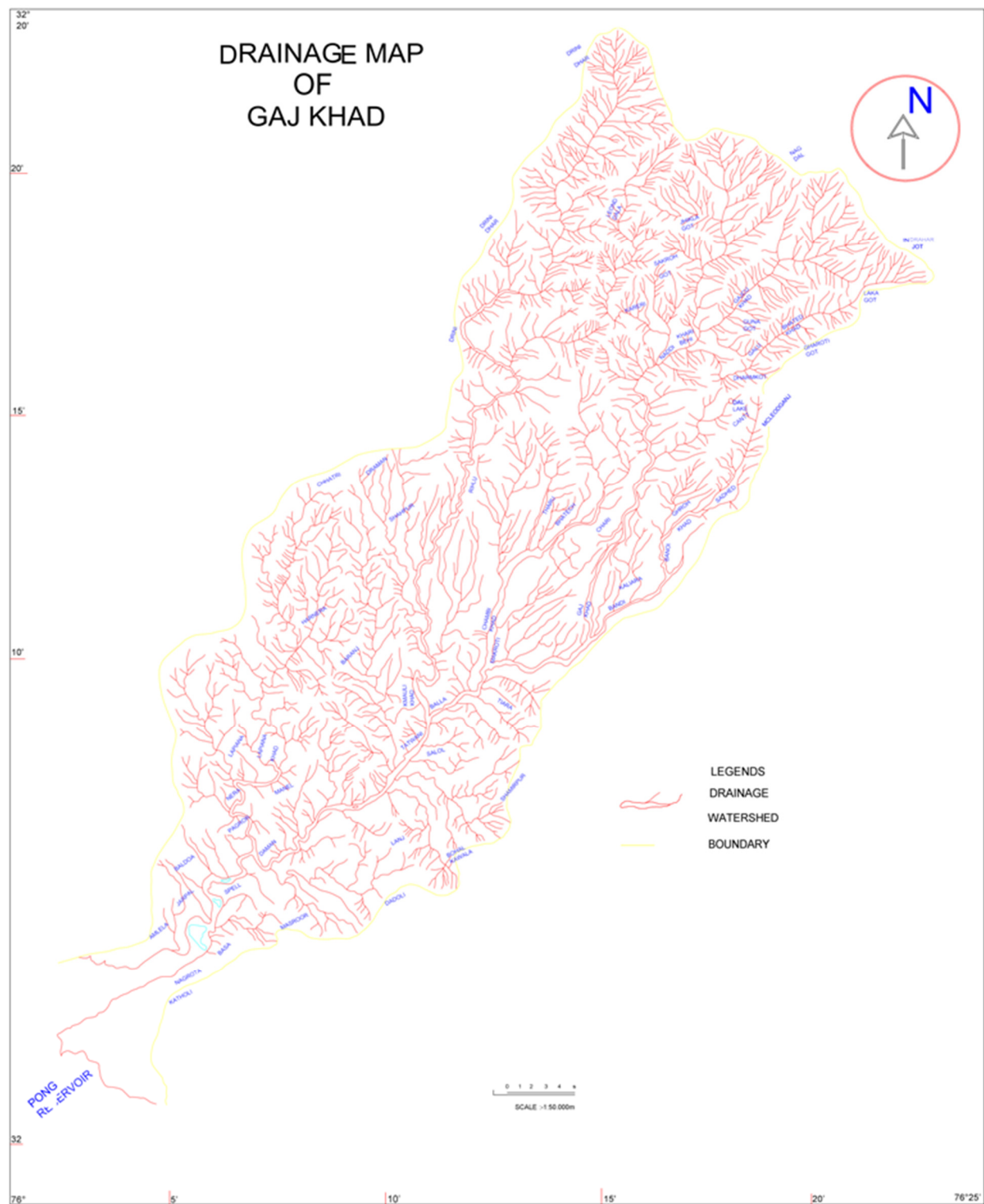


Figure 2: Drainage map of Gaj Khad watershed

Formation (Late Paleocene to middle Eocene), buff coloured Sandstones of Upper Dharamshla Group (Oligocene), Conglomerates and Sandstones from Siwalik Formation (Miocene to Pleistocene) and recent Alluvial deposits consisting of gravels, silts and sand (Fig. 3 and Table 1).

Table 1: The tectonostratigraphic sequence of the area (modified after Mahajan, 1991)

<b>Group/Formation</b>	<b>Age</b>	<b>Lithology</b>
Dhauladhar Granite	Precambrian	Granite
Chail Formation	Precambrian	Gneiss, pyllites, mica schists and schistose quartzite
-----Main Central Thrust-----		
Dharamkot Limestone Formation	Permian to Triassic	Grey Limestone, Dolomite and purple Shales
Subathu Formation	Late Paleocene to Middle Eocene	Purple Sandstone and Shale
-----Main Boundary Thrust-----		
Upper Dharamsala Group	Oligocene	Grey to buff coloured sandstone with red and grey shale
-----Drini Thrust-----		
Upper Siwaliks	Pli-Pleistocene	Boulder Conglomerate
Middle Siwalik	Upper Miocene to Pliocene	Sandstone with clay
Lower Siwalik	Middle Miocene	Sandstone with shale
Alluvium	Quaternary	Boulder Gravel, Sand silt and clay

Gaj watershed area is sandwiched between three prominent structural breaks (modified after Mahadevan, 1994), namely Main Central Thrust (Chail Thrust), Main Boundary Thrust and Drini Thrust. The Main Boundary Thrust (MBT) regionally separates the Lesser Himalayas from the Sub-Himalayas and shows moderate to steep northerly dips. The Dharamsala and Subathu Formations

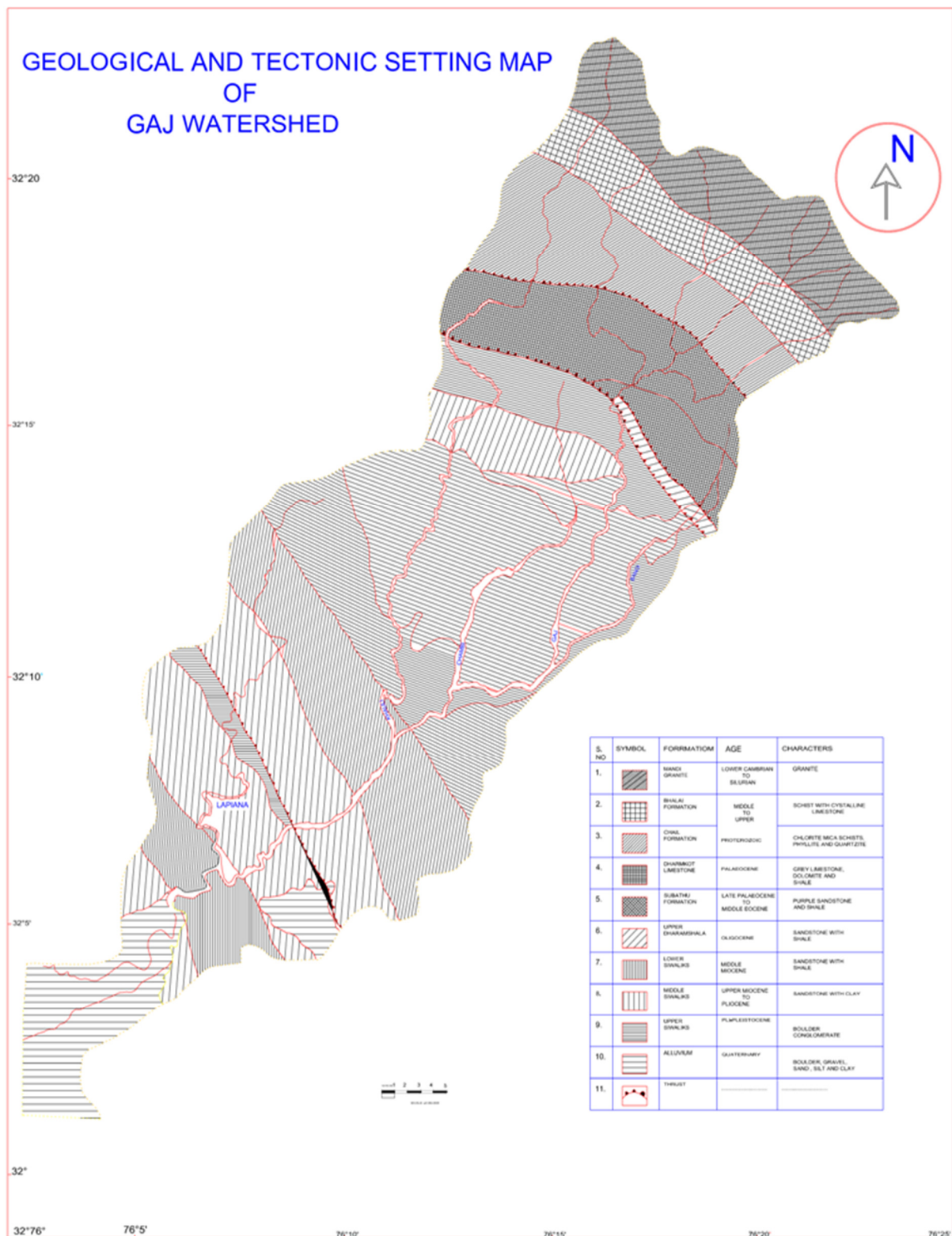


Figure 3: Geological and Tectonic setting of Gaj watershed are exposed between the MBT. Drini Thrust is a secondary fault of MBT which is separating Dharamsala Formation and Upper Siwalik Formation and is best exposed at Drini village. The Main Central Thrust (MCT) is essentially a ductile shear zone that separates the crystalline rocks of the Higher Himalaya from the Lesser Himalaya. Most of the subsequent subduction seems to be occurring along the MCT and MBT (Gansser, 1964). MCT is considered equivalent to Chail Thrust (Kumar and Mahajan, 2001).

**4. Morphometric Parameters :** Morphometric attributes of the study area are enumerated as under.  
**4.1 Stream Order**

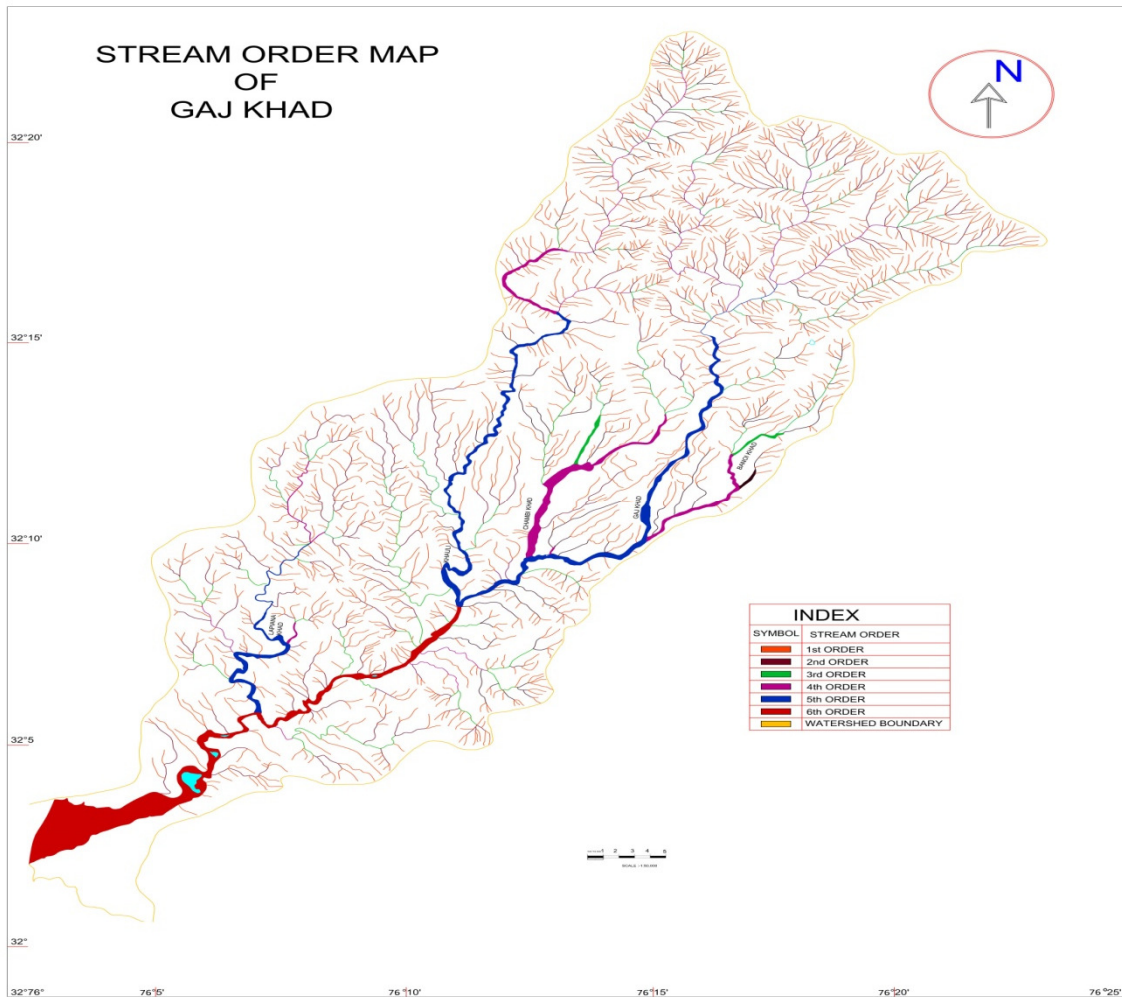


Figure 4: Stream order map of Gaj watershed

In the present study, ranking of streams has been carried out based on the method proposed by Strahler (1964). It is noticed that the maximum frequency is in the case of first order streams. It is also observed that there is a decrease in stream frequency as the stream order increases. In the present study area, the highest stream order segment is 6<sup>th</sup> order. Thus as a whole, the Gaj Khad basin is characterized by the streams from 1<sup>st</sup> to 6<sup>th</sup> order (Fig. 4).

**4.2 Absolute Relief (Ar)**

To determine the absolute relief, the study area is divided into grids of 1Km<sup>2</sup>. Using the contours given in SOI toposheets, maximum height of each grid is determined and is taken as absolute relief marked by isopleths techniques. The area is further divided into six zones having an interval of 800m. Results are given in Fig. 5.

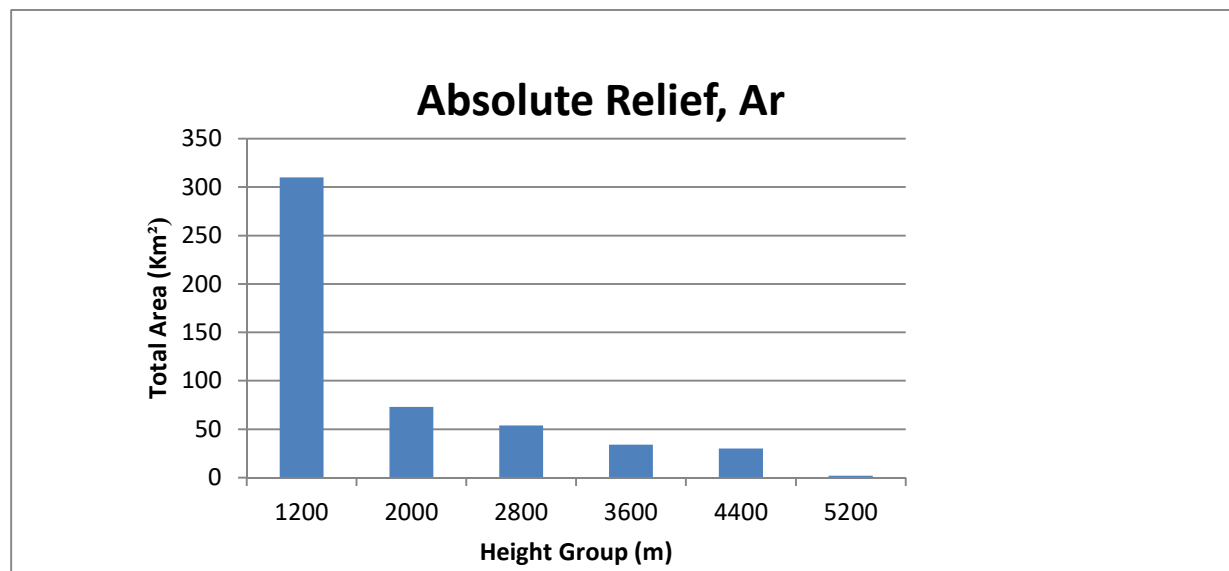


Figure 5 : Absolute Relief of the area

#### 4.3 Relative Relief (Rr)

Relative relief represents the difference of maximum and minimum heights of each grid. In the present study, the calculated relative relief range is 01-1200m. Using these difference values, the watershed is further divided into six groups having an interval of 200m each and the results are shown in Fig. 6.

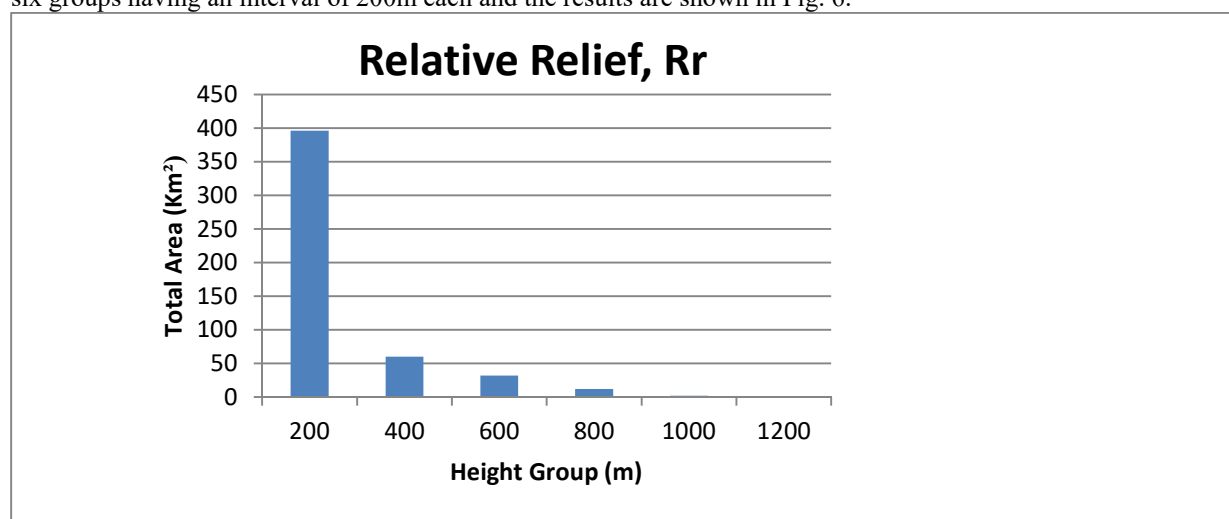


Figure. 6: Relative Relief of the area

#### 4.4 Erosion Intensity

Erosion intensity of the watershed is calculated using the formula given by Dove Nir (1957) and the value is further divided into four categories. The results are shown in Fig. 7.

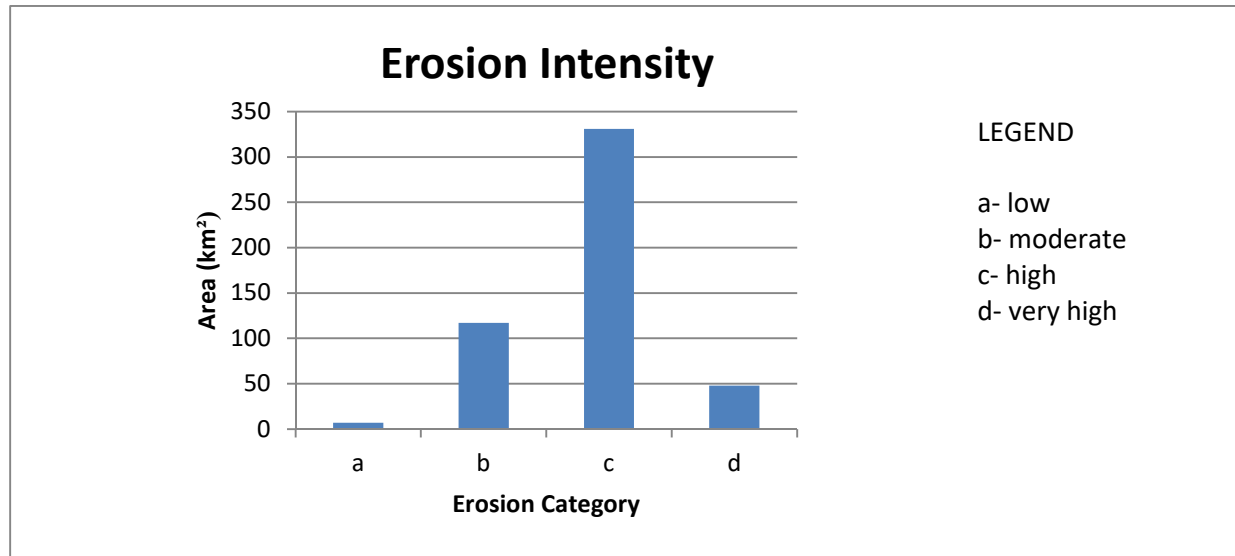


Figure 7: Erosion Intensity

#### 4.5 Drainage Density (Dd)

The drainage density indicates the closeness of spacing of channels (Horton, 1932). It is expressed by a formula:

$$Dd = \Sigma Lu / Au$$

Where Dd is the Drainage density,  $\Sigma Lu$  is the total stream length and Au is the area of that basin. The results are shown in Fig. 8.

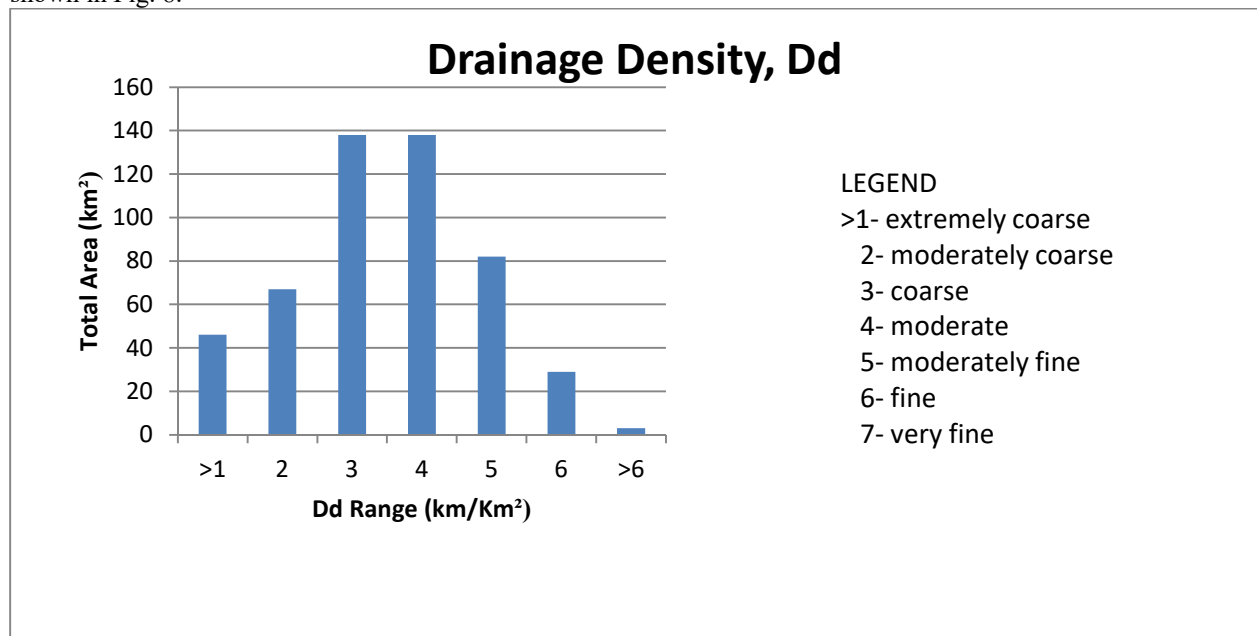


Figure 8: Drainage Density

#### 4.6 Stream Frequency (F)

The total number of stream segments of all orders per unit area is known as stream frequency (Horton, 1932). Stream Frequency is defined as the ratio between the numbers of stream segment per unit area which is expressed by a formula:

$$F = N / A$$

Where, N = Total stream segments of all orders of a basin

A = Drainage area of the basin



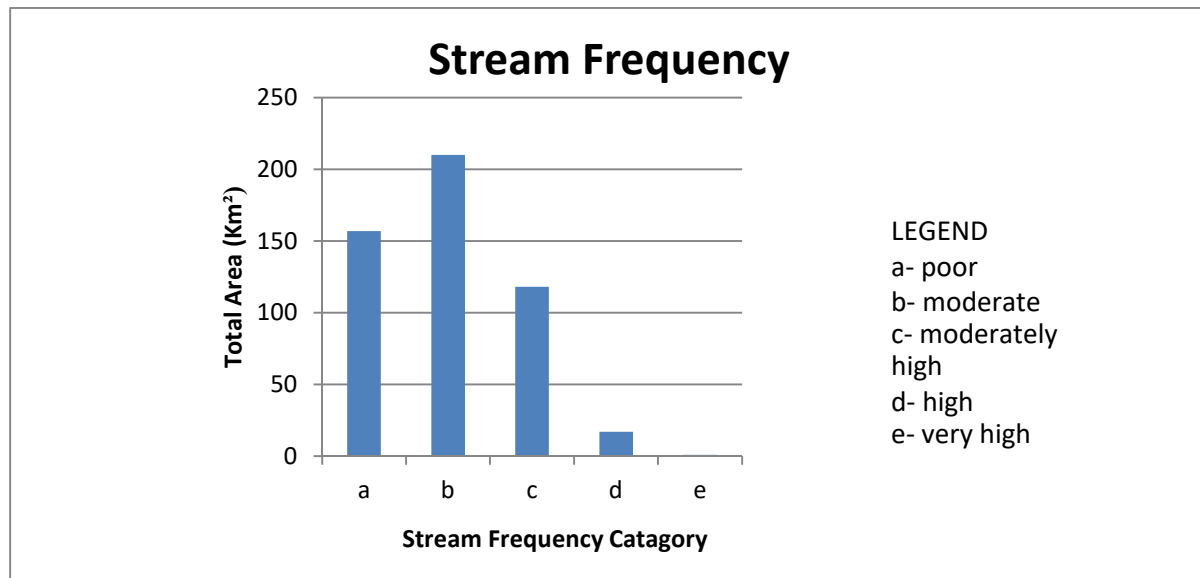


Figure. 9: Stream Frequency

#### 4.7 Slope Analysis

Slope is defined as the angular inclination of terrain between the mountain tops and the valley bottoms and is calculated by formula devised by Wentworth (1930):

$$\text{Average Slope (Q)} = \tan^{-1} = N \times CI / 636.3 \text{ m}$$

Where N= average number of contours crossing in an area and CI= contour interval. The results are shown in Fig. 10.

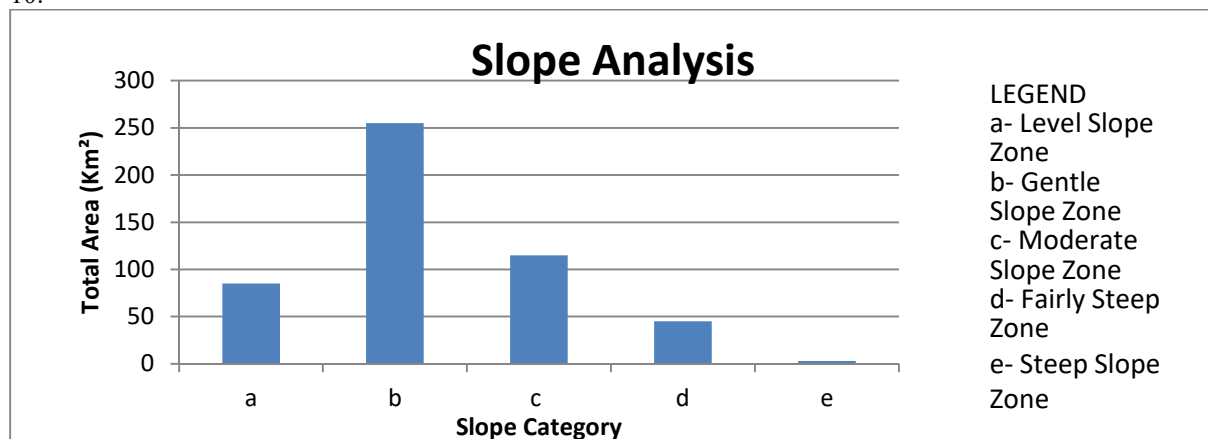


Figure 10: Slope Analysis

#### 5. Longitudinal profile.

Rivers are linear systems which show a gradient of characters along their length. Ideally the longitudinal profile of a river is concave with a steep upper portion near the source, giving way to reaches of progressively less gradient as the mouth is approached. However, if there is a change in the lithological character of rocks it is reflected in the profile of the river.

##### 5.1 Longitudinal Profile of Banoi Khad

Banoi khad makes the east boundary of the watershed area and originates at about an elevation of 2200m, near Mcloadganj Cantonment area. The relief limits of stream profile are 2200m (maximum) and 700m (minimum). The profile shows two breaks. First at 1190m elevation where a thrust separates Subathu Formation (purple sandstone and shale) and Upper Dharamshala Formation (Grey sandstone and shale) and second at at 900m elevation at Drini Thrust (Fig. 11).

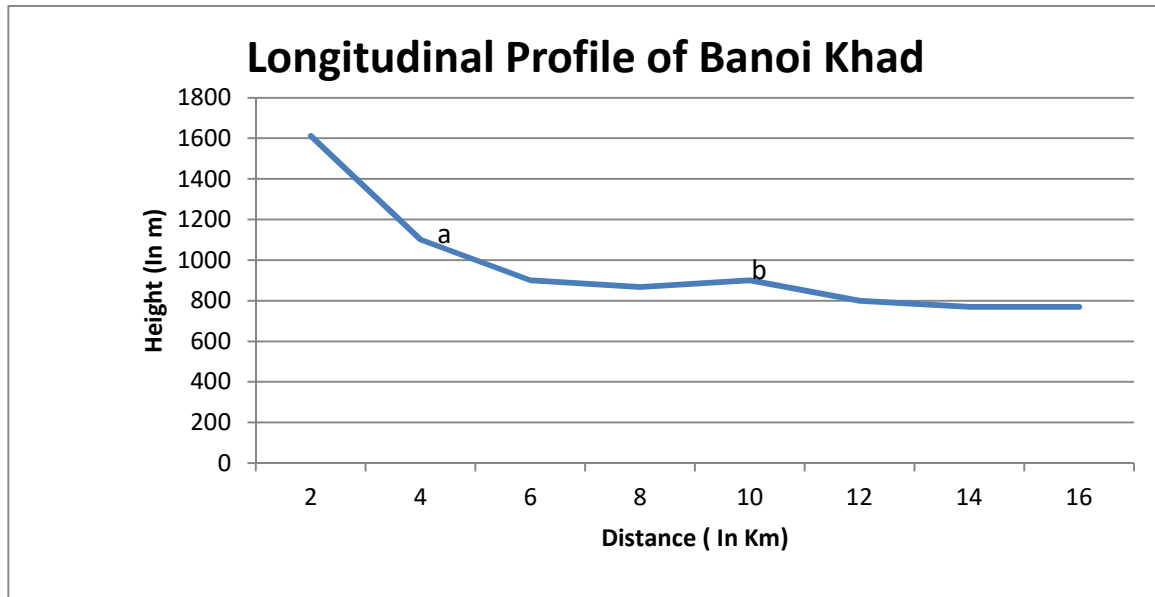


Figure 11: Longitudinal Profile of Banoi Khad

### 5.2 Longitudinal Profile of Gaj Khad

Gaj khad originates near Lam Dal (4200m) and the profile shows 4 breaks. First break in the profile is at 1800m elevation where MCT passes. Second break is at 1600m, which is due to a major fault which separates Dharamkot Limestone formation and Subathu Formation. Third break is at 900m elevation. Here, the khad starts flowing into Upper Siwalik (Conglomerate), leaving Middle Siwalik comprising of sandstone with clay. Fourth break is at 700m elevation. Here the lithology changes from Upper Siwalik to Middle Siwalik (Fig. 12).

### 5.3 Longitudinal Profile of Chambhi Khad

Longitudinal profile of Chambhi Khad is full with various convex and concave elements. First break in the profile is at 1300m elevation. Here the khad starts flowing to Middle Siwalik Formation and leaves behind Upper Siwalik Formation. Second break is at 900m, where lithology changes from Siwalik to Alluvium (Fig. 13).

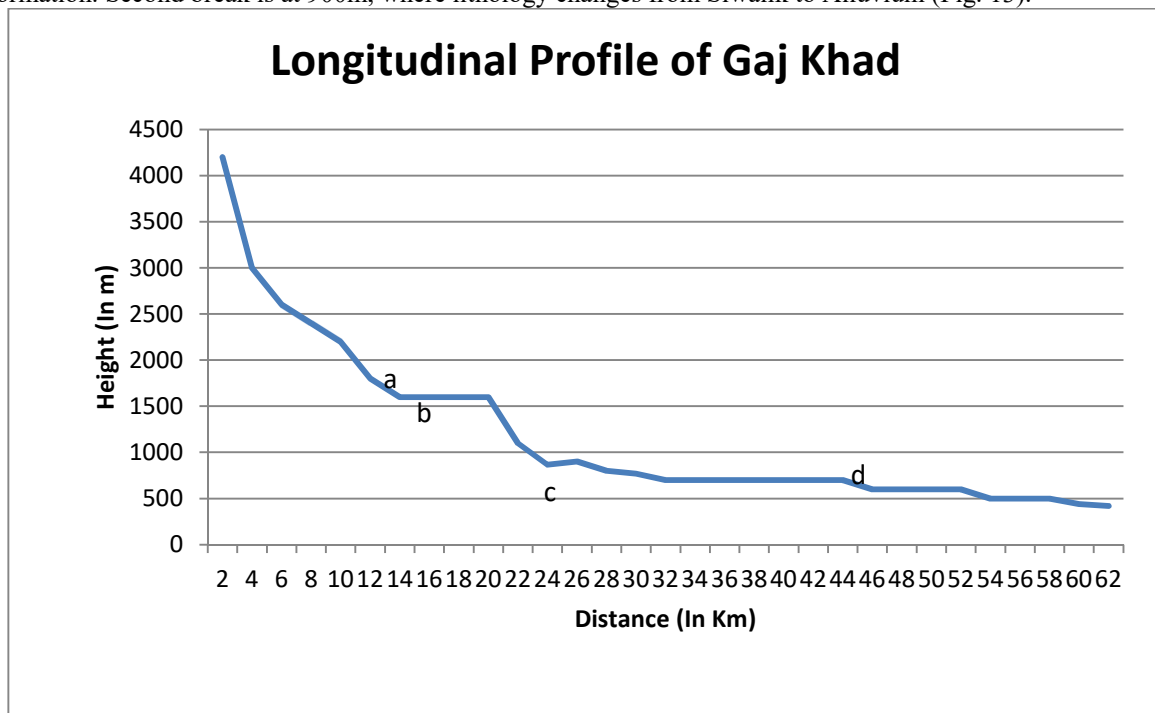


Figure 12: Longitudinal Profile of Gaj Khad

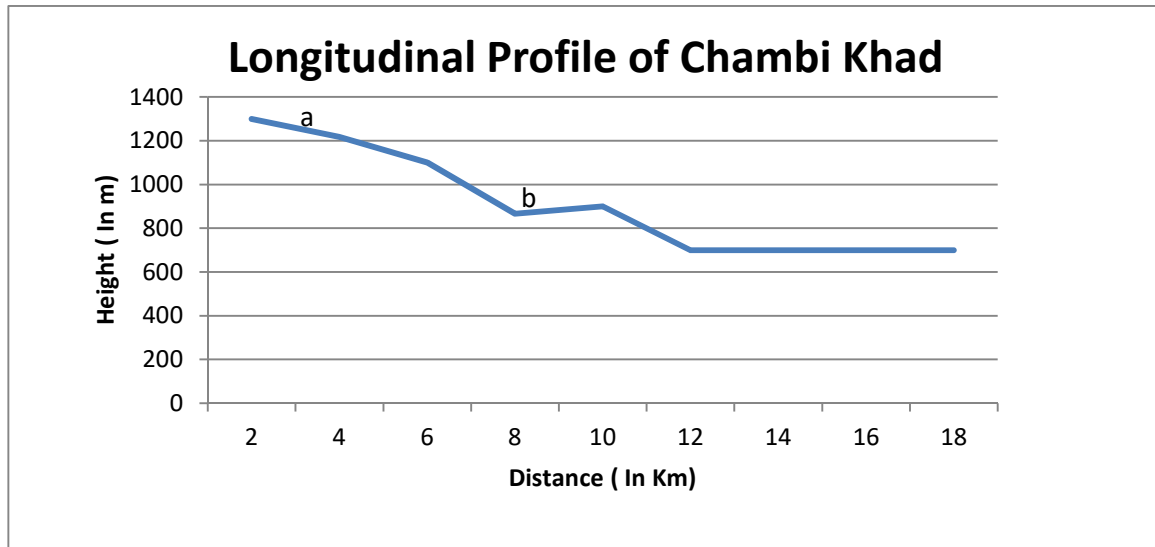


Fig. 12: Longitudinal Profile of Chambi Khad

#### 5.4 Longitudinal Profile of Khauli Khad

Khauli khad has the origin at 3800 msl near Drini Dhar (NW to Lam Dal) and the profile shows four breaks. First is at 2600m elevation where the khad starts flowing into Chail formation. Second break is at 2200m elevation. Here, the khad starts flowing into Dharamkot Limestone Formation, leaving behind Chail Formation. Third break is at 1600m elevation at Drini Thrust. Fourth break is at 900m elevation, where Siwalik Formation starts (Fig. 14).

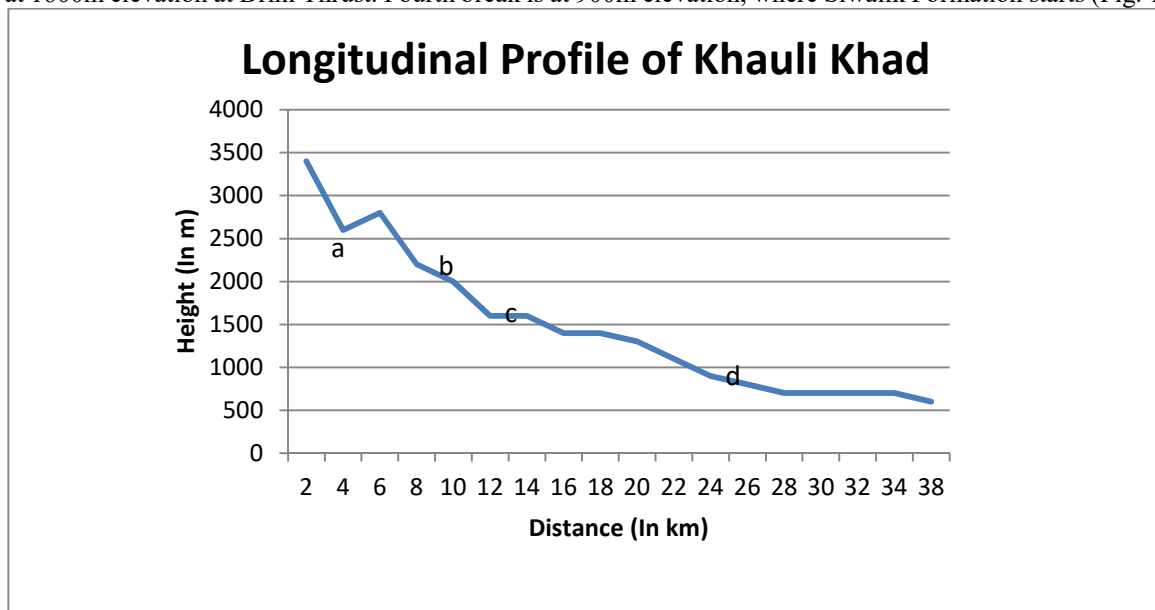
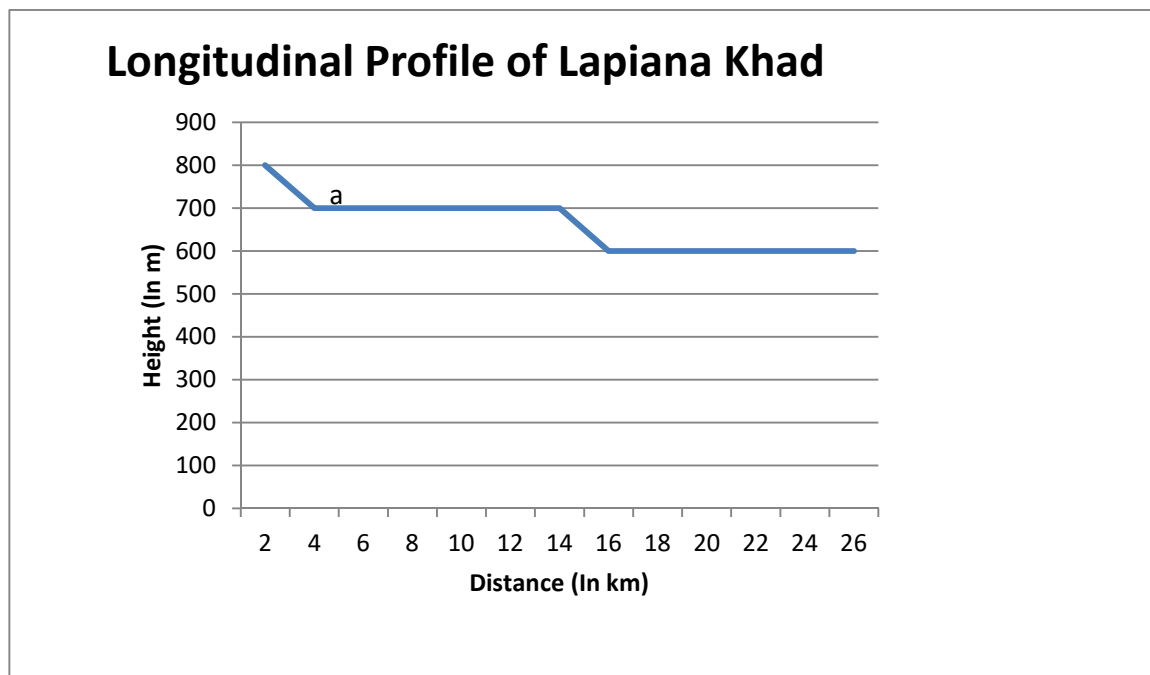


Figure 15: Longitudinal Profile of Khauli Khad

#### 5.5 Longitudinal Profile of Lapiana Khad

Lapiana Khad is comparatively shorter in length among all other tributaries of Gaj Khad and shows a little break in longitudinal profile at 700m elevation at Lapiana. Here, the Khad forms a number of meanders and finally merges into Gaj Khad (Fig. 15).



**Figure 15: Longitudinal Profile of Lapiana Khad**

#### **6. Interpretations of geomorphological and geomorphometric analysis:**

Present study reveals that Gaj Khad is 6<sup>th</sup> order stream. In morphometric analysis, absolute relief ranges from 418m to 4600m. Most of the area (61.63%) falls under 400-1200m absolute relief range and comprises mainly of alluvium and Siwaliks.

Relative relief ranges between 1-1200m, where 78.73% of area falls under 01-200m height range. Parts of Ghera and Chari village are found in this relief range. Only 2% of the total area falls under maximum relative relief zone and comprise mainly of Granites from upper reaches of Dhauladhars.

Sheet erosion, side erosion of river banks, creeps, landslides and slumping are encountered frequently in the Gaj Khad watershed area. Higher is the height variation, higher is the erosion intensity. Calculations reveal that about 66% watershed area experience channel erosion and gravitational slides and falls under high erosion zone. Higher reaches of Dhauladhar Granites experience such type of erosions.

About 28% of the total watershed area shows coarse drainage density. The area is composed mainly of Sandstones from Siwalik Group. The slopes are moderately steep in the region. Very fine drainage density covers only 0.60% of the total area, which comprises of upper reaches of watershed boundary and the slopes are highly steeper.

Calculation of stream frequency for Gaj Khad watershed reveals that about 42% area is of moderate stream frequency. This area mainly includes Dhauladhar Granites and Chail Formation and comprises of Granite, Phyllite and Gneiss. Slopes are steeper and the area falls under higher mountainous zone.

Longitudinal profiles of tributaries reveal the convex element for all profiles, but some breaks are evident in the form of concave element. These breaks are mostly encountered as lithological breaks, where the stream enters to a different Formation/Group and are correlateable to the complex lithology and diverse structure visible in the watershed area.

#### **Acknowledgement**

MG thankfully acknowledges the help and support she received from the research lab of Department of Geology, Government Post Graduate College, Dharamsala, Himachal Pradesh, India.

#### **7. Conclusion**

Due to peculiar geology and tectonic setting, most of the area of Gaj watershed is highly susceptible to erosion and land degradation. Gaj watershed area comprises of varied lithologies and is bounded by granites in the north and alluvial deposits in the southern end. The watershed area is sandwiched between major tectonic breaks, namely MCT and MBT and shows evidence of neo-tectonic activities along these active faults. Most of the areas are of high erosion intensity and results are visible in terms of frequent landslides and erosion in the area. Based on the morphometric investigations of the watershed area; it is postulated that the erosional processes coupled with

fragile and diverse lithology have dominating influence in the evolution of topography of the region. This study is useful to understand and plan the mitigative measures required for combating the effects of excessive erosion in the Frontal Himalayan region of Himachal Pradesh state.

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