Dhauliganga river originates from the famous glacier Kamet (7756 m), situated in north part of Chamoli district of Uttar Pradesh. The main stream of the river which comes from Dhaulagiri glacier is called Ganeshganga in its infant stage. In its early stage it flows in north-east direction and then takes a turn southward upto Bampa (3352 m). After this again it takes a sharp turn in eastward direction upto Kurkuti (Kailashpur, 3040 m) and flows along Dhar Martoli Fault, where Girthiganga flowing east to west-south direction makes its confluence with Dhauliganga. The river then flows southward till Kurkuti to Malari, where it makes a meander like shape, which is because of obstacle in the course of river by pleistocene glacial debris on which village Malari (3080 m) is situated. After Malari it takes a sharp turn towards west and flows in a deep gorge. Kosagad meets Dhauliganga on the west bank near village Kosa (3012 m), here again it flows in south direction in the dense reserved forest (dominated by Deodar) and crumbled, fractural and extremely complicated zone of central crystalline. Jelam (2985 m) is an another important village on the west bank of the river. Near the confluence point of Dunagirigad with Dhauliganga (originating from
Dunagiri glacier) river used to originally to flow in a very deep gorge which is now filled up by the heavy siltation brought by the Dunagirigad in the notorious flood of 1971-72. The relicts of trees in the river bed are an evidence of this catastrophe. Junagad meets Dhauliganga from right side near Juma village. Juma to Tamak, where Wauthigadhera meets the main river, Dauliganga flows in east west direction on the central crystallines of Garhwal Himalayas. The main rocks of the vicinity of the course are gneisses and schists. One and half kilometer below Tamak, Gankhwi Gadhera (source in Gankhwi glacier) makes its confluence with Dauliganga on the east bank near village Saigari. Gadigadhera on right bank and Phagitigadhera on left bank make their confluence with main river near village Gadikhark. From Gurmagwar to Lata for 7.25 kms river flows in a comparatively wider valley and near Lata it flows in the form of a braided river. Rishiganga a big tributary of Dauliganga joins near village Rini, which is an example of arrow pattern of settlement developed between the fork angle of both rivers. One and half kilometres from the confluence of Dauliganga and Rishiganga, Juwagwargad meets Dauliganga with a steep fall of 6 metres height. From Rini to Bilagarh, river flows eastward in a straight line and near Bilagarh it takes a sharp turn towards north. Homgadhera meets Dauliganga on right bank
near Khancha (1650 m). Here again river flows in a deep
gorge in east north direction and makes its confluence
with Alakananda at Vishanuprayag, where Alakananda comes from
north and takes a sharp turn about 90° towards west.

MAIN TRIBUTARIES:

Dhauliganga has following main tributaries which
contribute significantly to its discharge (Fig. 2.1):

1. RISHIGANGA:

Rishiganga, the main tributary of Dhauliganga originates
from Rishi glacier and it takes water from Uttar Nandadevi
glacier, Dakshin Nandadevi glacier and Uttar Rishiglacier.
The total length of Rishiganga is about 32 km. River flows
almost all in a straight line west ward and makes its
confluence with Dhauliganga near Rini village. The main
streams which join Rishiganga are, Rishikotgad which meets
the trunk stream by a fall of 30 metres on north bank.
Bangnigadhera, originating from Rammi glacier meets near
Ramni (3470 m). One and half km ahead Ramni, Trishuli Nandi
(originate from Trishul glacier, trishul peak, 7045 m)
meets Rishiganga in open mixed jungle. Rishiganga has a
water fall (25 metres high) in its course. 2 km before
the confluence with Dughganga, Dubrugethagad (originates
from Hanuman glacier) meets Rishiganga by forming itself
a steep waterfall of 50 metres height in its finger stream.
Another stream Raunthigadhera (source at Raunthi peak).
6,063 m) meets Rishiganga, 5 km below the confluence of Dudhgang.

2. GIRTHIGANGA:

Girthiganga is another important tributary of Dhauliganga, originating from Girthi glacier, which is situated in district Pithoragarh of Kumaon Himalayas. The water to Girthiganga is contributed by Najagaon glacier and Bhilmagar glacier which are situated in south-east part of the basin. Several branches of Girthiganga originate from different glaciers. The catchment area of Girthiganga has an elongated shape. The streams coming from both the sides (north and south) are small, less sinuous and numerous. Rockfall is a common phenomenon in the entire Girthiganga basin. The total length of Girthiganga is about 39 kms.

3. KIOGAD:

This stream has an origin in the nearby area of China border. The total length of the river is about 29 km. The main tributaries of Kiogad are Chidamugad and Yonggad. There are two water falls in the course of the trunk stream—one 8 metres high and another 6 metres high. The highest waterfall is in a tributary of Kiogad, which is 2.5 km before the confluence of Kiogad. The finger streams in the area are discontinuous. Rockfall is a common phenomenon of the Kiogad basin with boulders which are generally found in upper parts of the basin. In the basin very small area
is covered by scattered trees. Topography of the area is very rugged and difficult.

GEOIDENTITY OF THE STUDY BASIN:

Dhauliganga basin is a 6th order basin in Strahler's stream ordering fashion, developed on the left bank of Alaknanda river. It forms an unique shaped basin over an area of 1992 square kilometres. A general glance at the basin clearly gives a notion of different physiographic characteristics viz., the water divide of the basin is encircled by the high mountains with higher peaks including Nandadevi (7817 m). South and south-eastern portions of the basin are covered by glaciers. Valley of Dhauliganga is bit flat near Tapoban. South of the river, where maximum settlements of the entire basin are situated, some cultivable land is also available. Some patches of dense forest can also be observed in the central part of the basin from Joshimath to Malari along Dhauliganga and Rishiganga. Bare rock landscape may be observed in eastern portion of high altitudes with huge boulders under the phenomenon of rocks falling. The location of the basin is near the China border on the transitional area of Garhwal and Kumaon regions of U.P. Himalayas. Geographically, the Dhauliganga basin extends from 79°30'E to 80°15'E longitude and 30°15'N to 30°45'N latitude. Politically, the basin covers the area of Chamoli district of Garhwal region and Pithoragarh
district of Kumaon region, in extreme north region of Uttar Pradesh (Fig. 2.2).

**SELECTION OF THE STUDY BASIN:**

Dhauliganga basin situated in the lap of Garhwal greater Himalayas has been selected as a basic unit of the study on the basis of the recommendations of Chorley (1969) and Lee (1964), because of being a limited, convenient and usually clearly defined and unambiguous topographical unit, available in a nested hierarchy of sizes on the basis of stream ordering. Secondly, it is an open physical system in terms of inputs of precipitation and solar radiation and outputs of discharge, evaporation and re-radiation. The rationale of the selection of this particular basin is its location in higher altitudes over the extremely complicated, fractured and crumbled rock strata of central crystalline and sedimentary formations of Tethys zone. Himalaya the highest mountain of the world is of recent origin of tertiary period and possesses the diversity of processes and landforms, which is quite significant for the geomorphological studies. This dynamic Himalayan region has experienced several natural hazards of environmental degradation, one of the recent examples is the flash flood of 1970 in Dhauliganga and Rishiganga which alerted the habitats to raise their voice against degradation of environment of the region in the form of
'Chipko movement'. Several government projects are being sanctioned in this geologically unstable area, therefore, geoenvironmental assessment of the area is quite essential before any planning of the region. The other significant reason is the two distinct processes working in the basin i.e. glacial and fluvial processes over two distinct lithological formations i.e. metamorphic and sedimentary. A comparative study of the landforms developed by these two processes over two varying lithological formations will be of great significance.

CLIMATE:

Climate is an important factor in shaping and modifying the landscape of a region. The intensity of different exogenetic forces over a landscape is a phenomenon governed by climatic conditions of the region. The present study area falls under the humid zone of the country. The main sculpturing processes of topography are weathering and running water sub-ordinated by the action of glacier movement. The entire basin enjoys the extremes of temperature, rainfall and snowfall. The elevation of the area controls the different aspects of climate, therefore, it largely depends on altitude and varies according to the aspects of elevation. The elevation of the area ranges from 2000 m above mean sea level in the valleys in west and 7000 m in the snow bound Himalayas in the South and South east. Although,
a bit of tropical heat may be experienced in the valleys during the summer, the winter is severe. As most of the area of the basin is situated on the southern slopes of the Himalayas, monsoon currents penetrate through the deep valleys and result in maximum rainfall in the monsoon season (June to September) particularly in the valleys. The southern area of the basin also gets a considerable rainfall and snowfall during the winter season which lasts from mid November to March.

RAINFALL:

The available records of rainfall for the year 1985, at the three representative sites, show that there is extreme spatial variations as well as seasonal variations. Malari, the highest gauging station in the basin has recorded the lowest rainfall in any season, while coming down to the middle part of the valley, Reni has recorded five times more annual rainfall than Malari in any season and, it goes upto six times at the Tapoban. The following Table (2.1) explains the spatial variation in rainfall from higher altitude to lower altitude and similarly seasonal variations.

The table 2.1 shows that July and August are the rainiest months, which obtain 76% to 85% of the total annual precipitation. In the monsoon season, there are few occasions when there are spouts of heavy rain in the
Table 2.1: MEAN MONTHLY RAINFALL IN THE BASIN (Cm),
Year 1985

<table>
<thead>
<tr>
<th>Location</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Malari</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>18.06</td>
<td>59.21</td>
<td>8.10</td>
<td>35.16</td>
</tr>
<tr>
<td>2 Reni</td>
<td>38.25</td>
<td>0.0</td>
<td>28.06</td>
<td>70.16</td>
<td>137.50</td>
<td>25.16</td>
<td>166.56</td>
</tr>
<tr>
<td>3 Tapoban</td>
<td>66.23</td>
<td>10.0</td>
<td>21.08</td>
<td>112.00</td>
<td>263.00</td>
<td>60.00</td>
<td>462.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Malari</td>
<td>14.40</td>
<td>37.00</td>
<td>14.50</td>
<td>0.0</td>
<td>0.0</td>
<td>15.54</td>
</tr>
<tr>
<td>2 Reni</td>
<td>117.84</td>
<td>122.30</td>
<td>159.80</td>
<td>0.0</td>
<td>25.0</td>
<td>74.22</td>
</tr>
<tr>
<td>3 Tapoban</td>
<td>103.85</td>
<td>0.15</td>
<td>10.62</td>
<td>0.0</td>
<td>0.0</td>
<td>92.35</td>
</tr>
</tbody>
</table>

Source: U.P. Deptt of Irrigation (I&P Division), Joshimath.

Hills causing floods in the rivers. The amount of precipitation decreases rapidly after the month of September and it is lowest in November. During winter the precipitation occurs in the form of snow and ice.

TEMPERATURE:

The temperature of an area is an important factor which controls the climatic conditions and ultimately governs the sculpture of earth surface. It has already been mentioned that there is no meteorological observatory in the basin. Therefore, the account of temperature is based mainly on the records of the observatories in neighbouring areas, where similar meteorological conditions
prevail. Variation in the temperature is significant from place to place which depends on altitude. The temperature in high altitudes in summer is considerably higher in the open valleys, than the areas lying under shadow. January is considered to be the coldest month of the year with a mean maximum temperature $10^\circ C$ at a height of 2000 m. above the mean sea level, the mean minimum temperature being at the freezing point ($0^\circ C$). The cold waves in the wake of western disturbances often make winter conditions rigorous. The temperature in much lower at higher altitudes towards the area of glaciers and precipitation at higher altitudes occurs mostly in the form of snow which accumulates considerably in the valleys. After January, both day and night temperatures begin to rise, rapidly. March and June are the warmest months with a maximum temperature of $25^\circ C$ at 2000 m above sea level, $15^\circ C$ to $19^\circ C$ at 3000 m elevation and still lower at higher altitudes. With the onset of the monsoon currents, temperature falls slightly by about $3^\circ$ to $5^\circ C$.

**HUMIDITY:**

The humidity in the area is highest during the monsoon period and also for a short spell when the region is affected by western disturbances. Generally sky remains clear or lightly clouded during the rest of the year.
The natural vegetation of the area may be classified into four categories according to the height and type of vegetation viz., Chir forest, coniferous forests and short bushes, flower plants and lichane. Few patches of dense forest occur in the area (Fig. 2.3) mainly in the river valleys. Chir forests occur in the area of low altitudes up to the 2200 m height on a south aspect. Chir trees are dominating because of their power of removing away other vegetation from the area where they grow. Chir is the staple building timber in the hilly tract and a large quantity of it is exported to the plains in the form of sleepers. Resin is also extracted from these trees and their seeds are eaten.

The species of coniferous forests are dominating between the altitudes of 3220 m and 4000 m. The chief species of the coniferous forest in the area are Ragha (Himalayan silver fur) and Deodar, which mainly occur between the heights of 3250 m to 3550 m.

Above the height of 4000 m some short bushes, green grasses and alpine vegetation may be observed. Lichan small grasses and beautiful flowers are the common phenomenon in the spring season, which comes here late.
LANDUSE OF THE BASIN:

The general landuse of the study area may be classified broadly into five categories viz., the area under cultivation which is available in the vicinity of Joshimath along the south bank of Dhauliganga, area under settlements which may be observed along the rivers in valleys, forested land which is also observed in river valleys along main rivers of the basin. Glaciated landscape is well developed on high mountains which is spread in south and south-east area of the basin and other hilly bare land scape. The distribution of land under above mentioned categories is exhibited in the map (Fig.2.3) and area of each category is demonstrated in the numerical terms in the Table (2.2) below (approximate).

Table 2.2: LAND USE OF THE BASIN

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Land Use Categories</th>
<th>Area</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cultivated land</td>
<td>23</td>
<td>1.15</td>
</tr>
<tr>
<td>2.</td>
<td>Settlements</td>
<td>42</td>
<td>2.11</td>
</tr>
<tr>
<td>3.</td>
<td>Forested land</td>
<td>248</td>
<td>12.44</td>
</tr>
<tr>
<td>4.</td>
<td>Glaciated Area</td>
<td>592</td>
<td>29.75</td>
</tr>
<tr>
<td>5.</td>
<td>Naked mountains</td>
<td>1087</td>
<td>54.54</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>1992</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

The Table (2.2) and map (Fig.2.3) clearly portray the maximum area of the basin lies under the hilly and
glaciated landscape, which is 84.29% of the entire basin. Very few patches may be observed under cultivated land, which are generally in the south of Dhauliganga from Rini Village, situated on the fork of Dhauliganga and Rishiganga to Joshimath urban area. This is the area which lies below a height of 3000 m and is rather flat, comparatively. Maximum settlements of the basin are also observed in this area and some are scattered along Dhauliganga up to Malari which is an important settlement in the basin situated on the confluence point of Dhauliganga and Girthiganga. Other important settlements of the area are Passani, Khanla, Balgaon, Biogarth, Reagaon, Tapoban, Ringi, Karchhigoon, Soldhan, Subhain, Reni, Lata, Paing, Markura, Juma, Jelam, Garpak, Kosa, Kurkuti and Bampa etc. The glaciers in the basin which contribute water to Dhauliganga and its contributories are, Kamet and Dhaulagiri in north, Gankhuvi glacier, Dangri bank, Siraunch gaul, Kalla bank, Lampak gaul situated in south-eastern corner of the basin. The big glaciers of the basin are, Uttar Rishi glacier, Dakshini Rishi glacier, Uttar Nanda Devi glacier, Dakshin Nanda Devi glacier, Trishul glacier, Hanuman glacier, Battartali glacier, Raunthi glacier, Nanda Ghungti glacier and Changbang glacier etc. all of which are situated in south part of the basin (Fig.2.3).
GEOLOGICAL BACKGROUND:

The geological background of the Dhauliganga basin is directly associated with the geological episodes of the upliftment of the Himalayas. The present topographical features of the area are a result of endogenetic and exogenetic forces working in the region. Unless those stages of upliftment are not clarified, the present landform features can hardly be explained. So, for a clear understanding of present landscape it is a must to look back into the main episodes of its upliftment history. The upliftment history of the Himalaya is summarised below.

UPLIFTMENT OF THE HIMALAYA:

It has now been well established that the Himalaya did not attain its present height in one single phase. Geological data show that Himalaya has developed during five or more phases of upliftments with intervening periods of quiescence. The first movement took place during the middle to upper cretaceous when the Tethys was furrowed into a series of ridges and basins running longitudinally. Into the basins we had the deposition of Palaeocene - Eocene rocks (Subathus in lesser Himalayan). Then followed a period of comparative rest after which another upheaval took place during the upper eocene after which the sea nearly vanished and brackish water deposits of Dagshai-Kasauli or murees were formed. The third movement which was probably most powerful of all, took place during the
middle Miocene times. During this period the Himalaya acquired its major features and the Tethys completely vanished being replaced by mountain ranges with shallow marches and large river valleys. At this time a long narrow trough or fore-deep in front of the rising Himalaya was formed in which fresh water Siwalik sediments were deposited by the river flowing from the Himalaya and the Peninsular India.

At the end of the Siwalik sedimentation i.e. towards the close of the Miocene, a fourth upheaval took place. This was followed by an ice age during Pleistocene. The final phase of Himalayan upliftment took place in early Pleistocene when Pir Panjal was raised to its present height. This happened in other parts of the Himalaya as well. This is evidenced by the occurrence of Pleistocene deposits on the flanks of the Pir Panjal, several thousand feet above the level of lakes in which they were originally deposited. Before this movement, man had already appeared on the globe and must have witnessed the final phases of the rise of the Himalaya. Minor adjustments have been taking place since then, as some of the faults are still active.

The Himalayas are still rising is evident from the presence of river deposits hundreds of feet above the present river level. The geological information in the basin can be categorised under 2 heads—schists and gneisses
of older formation associated with sedimentaries of newer formation. A detailed account has been provided below on the basis of Heim and Gansser (1939).

THE BADRINATH GROUP (THE UPPER ALAKNANDA) TECTONICS AND GEOLOGY:

Descending to the gorge at Vishnuprayag, the gneiss is exposed below the slide block field. It is biotite gneiss with minute fluidal folding of the Darjeeling type. Above it, also regionally dipping 45° to N 10 E, follows a repetition of highly metamorphic mica schists and paragneiss with injections of the following approximate thickness:

a) 1200 metres of chiefly mica schists with garnet;
b) 400 metres of chiefly gneiss;
c) 700 metres of chiefly mica schists with garnet;
d) 9400 metres of quartzite with subordinate mica schists.

With slight changes of the strike, the dip of this enormous mass of well-bedded quartzite varies from 40-70°. No indications of tectonical repetitions having been found, we are forced to consider (Heim and Gansser, 1939) it as a normal succession. Only above the waterfall of Kaliankoti, between the two iron bridges, the rock changes into a highly metamorphic sedimentary series with injected augen gneiss, characterised by lime-silicates. The dip is 55-65° to N 15 W.
The next sub-division sets in with a series of quartzites and lime silicates, injected and inter bedded with amphibiotic layers. The latter can also be traced on the walls on the west side of the valley by their rusty weathering. This series shows minute zig zag folding.

The last two sub-divisions have a thickness of about 1.5 kilometres. The trail following the east side of Alaknanda now enters moraines. As seen from the distance, on the high walls of the western side, the injected series with lime-silicate layers continues and gradually steepness to a vertical and even over vertical position in the shape of a synclinal fan. Its vertical axis, striking W20°s, passes the river below the Bamani, 1.5 to 2 km south of the temple of Badrinath. There, the succession towards the north is as follows:

a) Biotite gneiss and mica schists, about 80 metres dip 80° to s 30 E;

b) Banded lime - silicates, about 100 metres;

c) Gneiss and gneiss - quartzite, dip 60° to S 25 E;

d) Highly metamorphic sediments with injected gneiss and calc silicates forming a flat anticline, of 10-20° pitch to W 15 S, thickness about 1 kilometre.

Summarizing the Alaknanda section from the thrusted basal mica-schists and gneisses at Urgam valley up to Badrinath. Heim and Gansser (1939) found the three following sub-divisions, of which the first two are
apparently in a normal succession:

1) 7.8 kilometres mica-schists with gneiss;
2) 9.4 kilometres quartzite ("granulite");
3) About 4 kilometres of injected paraschists characterised by lime-silicate layers.

This latter series, above Mana and thence to the west becomes to a great extent replaced by granite with aplitic dykes and sills.

DHAULIGANGA AND RISHIGANGA:

On the north side of Kauri pass, the Dhauliganga has formed a deep valley in the shape of an arch with its convex side turned to the south, first making a transverse section and then cutting a longitudinal valley down its confluence with the Alaknanda at Joshimatha - Vishnuprayag. The rocks are mica schists with quartzite layers, alternating with real biotite gneiss which becomes predominant towards Joshimath. The dip is 20° to N and NNE at the Kuari Pass and gradually steepens up to 45° towards N. (Fig.2.4).

About 2 km below the mouth of Rishiganga, the trail passes over a spur of gneiss with muscovite, biotite and kyanite together with layers of marble and lime silicates dipping 38° to E 25°N.

In the Rishi Gorge, the mica schists, full of garnet, still dipping 30°, strike to S 30 E, and on the north side of Nandakana, already seen at a long distance, the strike is
TRAVERSE MAP

CENTRAL CRYSTALLINES OF GARHWAL HIMALAYA

- CALC-ZONE (GARHWAL GROUP)
- TETHYS ZONE
- GNEISSES AND SCHISTS
- M.C.T. MAIN CENTRAL THRUST
- D.M.F. DHAR-MARTOLI FAULT

SOURCE: HIMALAYAN GEOLOGY, VOL. V, 1975, P. 456
seen S 15° E. The strike from Joshimath forms thus a wide arch, turning from nearly east to nearly south. Joshimath lies in the prolongation of Nandakana.