CHAPTER III
DESCRIPTION OF THE EXPERIMENTAL TORRENT WATERSHEDS

3.1 Introduction

For the purpose of the studies reported here in, a part of the drainage basin of the Asan river (a tributary to Yamuna river) in the western portion of the Doon Valley, which is affected by serious torrent bed widening problems was chosen. A total of ten torrents—five originating in the Himalayan foothills in the north and five others originating from the Shiwaliks in the south have been chosen.

Both the sets of torrents drain into the Asan river which flows longitudinally in the syncline. The torrents selected for the studies from the Himalayan foothills side are, the Gulaitanadi, the Darernadi, the Bansiwala Rao, the Bainskhala and the Chorkhala while from the Shiwaliks side, the Ogipani Rao, the Ramgarh Rao, the Kaluwala Rao, the Bhul Rao and the Sukh Rao have been selected (Fig. 3-1). The Central Soil and Water Conservation Research and Training Institute's Research Farm at Selakui (Latitude - 30° 19' N, Longitude - 78° 02' E and Altitude - 680 m above MSL) which is more or less located centrally in the study area served as a base for the experimental work. While selecting torrents on the Himalayan foothills side, the bigger streams originating right from the Outer Himalayas like the Tons and the Suarnanadi have been avoided as their catchments are very large and their streams in the upper reaches are very steep which make the collection and
Fig. 3-1 Location map of the study area
transport of bed material (the studies of the variation of which forms part of this work) prohibitive, if not altogether impossible. Therefore, the streams originating near the fan heads, downstream of the Main Boundary Fault, have been considered on the Himalayan foothills side. On the Shiwaliks side, however, all the selected torrents originate from the Shiwalik ridge line. In some of the Shiwalik streams which split in the downstream reaches, the unsplit upper reaches of the streams are only considered. The exact locations of these torrents are given in Table 3.1.

The description of the study area including location and geography, geology and geomorphology, drainage, climate, soils and natural vegetation is given in the following sections.

3.2 Description of study area
3.2.1 Location and geography:

In the Outer Himalayas a number of conspicuous longitudinal valleys occur, which are known as Duns and the largest of these is the Dehradun Valley which in short is called as Doon Valley. It is an intermontane tectonic synclinal valley located between the Outer Himalayas in the north and Shiwalik ranges in the south. The rivers Ganga and Yamuna form the eastern and western boundaries of the valley respectively. The Doon Valley proper is separated from the Lesser Himalayas (Chakrata, Bhadraj and Mussoorie ranges) by the Main Boundary Fault which is a tectonic feature extending in NW-SE direction. The valley is roughly an
Table 3.1 Location details of the selected torrents in Doon Valley

<table>
<thead>
<tr>
<th>Name of torrent</th>
<th>Longitude</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Himalayan foothill torrents</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Gulaitanadi</td>
<td>77°-57'-06&quot; to 77°-58'-34&quot; E</td>
<td>30°-20'-25&quot; to 30°-24'-51&quot; N</td>
</tr>
<tr>
<td>2. Darernadi</td>
<td>77°-56'-15&quot; to 77°-58'-15&quot; E</td>
<td>30°-20'-58&quot; to 30°-25'-33&quot; N</td>
</tr>
<tr>
<td>3. Bansiwala Rao</td>
<td>77°-54'-10&quot; to 77°-54'-56&quot; E</td>
<td>30°-20'-38&quot; to 30°-25'-00&quot; N</td>
</tr>
<tr>
<td>4. Bainkhala</td>
<td>77°-59'-00&quot; to 77°-57'-00&quot; E</td>
<td>30°-20'-51&quot; to 30°-24'-48&quot; N</td>
</tr>
<tr>
<td>5. Chorkhala</td>
<td>77°-49'-17&quot; to 77°-56'-16&quot; E</td>
<td>30°-23'-05&quot; to 30°-26'-35&quot; N</td>
</tr>
<tr>
<td><strong>Shiwalik torrents</strong></td>
<td></td>
<td></td>
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<tr>
<td>6. Ogipani Rao</td>
<td>77°-51'-45&quot; to 77°-52'-53&quot; E</td>
<td>30°-15'-43&quot; to 30°-18'-42&quot; N</td>
</tr>
<tr>
<td>7. Ramgarh Rao</td>
<td>77°-50'-52&quot; to 77°-52'-56&quot; E</td>
<td>30°-16'-12&quot; to 30°-18'-42&quot; N</td>
</tr>
<tr>
<td>8. Kaluwala Rao</td>
<td>77°-49'-50&quot; to 77°-51'-35&quot; E</td>
<td>30°-16'-33&quot; to 30°-18'-36&quot; N</td>
</tr>
<tr>
<td>9. Bhul Rao</td>
<td>77°-48'-53&quot; to 77°-51'-07&quot; E</td>
<td>30°-16'-53&quot; to 30°-29'-37&quot; N</td>
</tr>
<tr>
<td>10. Sukh Rao</td>
<td>77°-47'-18&quot; to 77°-49'-00&quot; E</td>
<td>30°-18'-00&quot; to 30°-21'-37&quot; N</td>
</tr>
</tbody>
</table>
undulating parallelogram with a maximum length of 72 km diagonally from North West to South East and 35 km from North to South at the maximum range. Precisely the valley is located within 29° 55' N to 30° 30' N latitudes and 77° 35' E to 78° 20' E longitudes covering an area of 2002 km² ranging in elevations between 300 m (990') and 2500 m (8250') above MSL (Anantharaman, 1981). Though it appears as a single continuous oblique valley, in reality, it is composed of two longitudinal sub-valleys comprising the drainage basins of the Asan and Suswa rivers which drain into the Yamuna and Ganga rivers respectively. A low water divide ranging from 610 m (2000') to 1830 m (6000') above MSL running along Saharanpur-Dehradun road from Mohand Pass upto Majra and thence in an almost straight line past the Dehradun Cantonment to Rajpur and to Mussoorie separates these two sub-valleys (Saxena, Anantharaman and Pandey, 1978). The Asan river rising from a clayey depression near Gorkhanala at Chandrabani, situated to the west of the Dehra-Asarori water divide at an elevation of 606 m above MSL flows westwards to meet the Yamuna river at Dhalipur after covering a total course of 41 km (Walton, 1911) and draining an area of 651 sq km. The study area, as reported here in, comprises of a part of the drainage basin of the Asan river in its middle reaches (vide Fig. 3-1).

3.2.2 Geology and geomorphology:

Geologically the Doon Valley is subdivided into three broad units (Medlicott, 1964; Auden, 1934):
1. The lesser Himalayan mountains of the Mussoorie - Bhadraj - Chakrata ranges in the north which comprise of Simla slates, Chandpur phyllites, Nagthat quartzites, Blaini boulder bed, Infra Krol shales and limestones. This region comprises of 20% of the Doon Valley.

2. In the centre the Dehra Dun Valley proper which is a synclinal valley, comprising of Pleistocene and Holocene gravels (the Dun gravels) forms 45% of the valley. The lithology of this region includes consolidated and unconsolidated gravels, pebbles, conglomerates and boulders. It has low relief and a very gentle slope.

3. The Shiwalik ranges to the south which are composed of lower, middle and upper Shiwalik conglomerates, sand stones, shales and clay.

Several large size fans descend from the Himalayan front into the Doon Valley. They coalesced together to form the piedmont plains on which the torrents flow. These plains are characterised by very coarse boulders with a sandy and silty matrix. The size of the boulders, cobbles and pebbles decrease progressively with the distance away from the mountains. The soil texture also becomes finer farther away from the mountains though cobbles are still noticed on the soil surface.

The upper reaches of the piedmont are
characterised by the presence of block faulting, hanging streams and minor faults. As a result, the area is extremely dissected and large number of sub-parallel streams are found in this area. The dissection by streams is deep and stream beds are lined with boulders, cobbles and pebbles. Side slopes are abrupt and very deep but are usually covered with good vegetation.

The lower reaches of the piedmont are typified by parallel drainage patterns. The area has slopes varying from nearly flat to undulating. Soils are deep typic Hapлюдolls and are fast erodible.

The Shiwaliks are divided into two regions, the northern and the southern Shiwaliks. The north Shiwalik zones drain into the Doon Valley and are hence of concern in the studies. The folded lower and middle deposits stand as hills. The gravel is a valley fill in the pre-existing relief. The Shiwalik rocks of this zone are well rounded and are broken hard quartzitic sand stones which appear to have been derived from the lesser Himalayas. The area is mostly under good forest cover.

The catchment area of various streams have a direct influence on the properties of various sediments deposited by them. The streams from the Outer Himalaya drainage line produce calcareous materials while the streams from the Shiwalik drainage line bring down siliceous material. Similarly there is a great difference in piedmont
fan material in the Himalayan belt and the Shiwalik belt. While in the case of the former, the piedmont material is composed of coarse fractions of platy shales, slate and quartzite fragments, the piedmont material from the latter consists of pebbles, cobbles and gravels at varying depths below the soil surface.

3.2.3 Drainage:

The drainage of the Doon Valley reflects the monsoon conditions prevailing in the area as well as the geomorphic and tectonic youth of the area. Several drainage systems have been recognised for Doon Valley (Anantharaman, 1985 and Nossin, 1971). They are the south Shiwalik system, the north Shiwalik dip slope rivers, the principal fan drainage, the mountain front drainage, the longitudinal Doon rivers and the antecedent trunk rivers of Yamuna and Ganga (Nossin, 1971).

Generally, the rivers experience a considerable loss of gradient upon entering the Doon Valley from the Himalayan front, and as a result they assume a braided pattern soon after. Braided conditions are the most common in all the Doon Valley streams, in fact rivers that have not braided are extremely rare (Nossin, 1971). The braiding may be due to the loss of capacity of the streams upon entering the Doon Valley. However, even rivers rising on the fan surfaces show braided channels. This may be attributed to the large supply of ready load from the pebble fan deposits or, in places, from the Upper Shiwalik formations.
Similarly, all dip slope streams flowing down the northern slope of the Shiwalik Range have braided channels and are oversaturated with pebble load. The other important factor facilitating the braiding of channels is the relatively small resistance of the pebble deposits against lateral erosion undercutting.

The lower portions of the stratum of Doon Valley is underlain by pebble and gravel deposits, the thickness of which is not exactly known. The porosity of these deposits is great and much of the discharge disappears underground in the river bed itself. Resurgence occurs, sometimes in the downstream reaches of the larger rivers of the Doon. Sometimes the streams lose their course altogether and cease to exist because all their discharges disappear underground.

Except for the Yamuna and the Sanga, the two main rivers which have perennial flow, all other rivers in the area are seasonally dry, and have only a sizeable discharge during and after monsoon rainfall periods. In the monsoon season the rivers often attain full flow within short periods and the capacity and competency of the streams increases manifold. This sets in motion the coarse material and transports them downstream as long as the spate conditions prevail.

A geomorphological map at Fig. 3-2 outlines the geomorphology of the study area (Nossin, '971). According to
it, the study area comprises of north-easterly dipping slopes of Shiwalik Range in the south starting from the ridge of the Mohand Hill Range. The upper reaches are ravined with scarp faces comprising of the upper Shiwalik pebble conglomerates. Changes in the gradient take place at a short distance and the upper Shiwalik rocks disappear under the alluvial fan deposits giving rise to piedmont formations of the Shiwalik origin. Asan river is the principal river that drains the study area and separates the dip controlled slopes of the northeast face of Shiwalik Range from the northern unit of principal Doon fans, both showing different lithological characters, being essentially derived from two different sources. They, therefore, also bear different soil characters which are of variable nature. Compared to the Shiwalik piedmont zone, the pre-tertiary piedmont terrain is much gentler and occupies a much larger area.

The drainage is of two types. The principal fan drainage and the mountain front drainage. The mountain front drainage rises on the mountain front of the Lesser Himalayas of Mussorie Range and plunges into the Doon Valley. It is deeply incised below the fan surface, usually with three or four terrace levels. The rivers experience a sharp loss of gradient upon entering the valley. This sharp kinck is to be attributed to the Main Boundary Fault. The principal fan rivers rise in the northern realm of the main fans and have a southward tendency. These streams are consequent, braided
and flow over the fan surface rather than in it though the rate of incision varies from place to place.

Although no mountains occur in the immediate vicinity of the study area in the principal Doon fan unit, yet it may not be out of place to mention that drainage from the mountain front or beyond, is well incised into the fans from level 600 ft (183 m) at Doonga (Suarna nadi) to 450 ft (137 m) (Nossin, 1971). Near the fan heads, the underlying rock is often exposed. The drainage which rises on the fan surface itself is, however, hardly incised in it at all. The fan surfaces have smooth gradients and they have not been dissected. According to Nossin (1971) huge tracts, as well as the present river beds and their terraces have all been derived from the upper Shiwalik conglomerates.

3.2.4 Morphodynamics of the streams:

Based on the field observations the morphodynamics of the streams in the area is described as follows (Dhar, 1985):

1. Both sets of the experimental streams i.e., those originating in the principal Doon fans and those originating from the Shiwaliks show almost relatively straight courses.

2. Asan Rao and its major tributaries are braided, carry heavy sediment loads; the sediments being medium to coarse grained, the channel bed infiltration is high, and the flow velocities do
not keep pace with the sediment yields.

3. The streams of Shiwalik origin are relatively more braided since they drain comparatively steeper slopes.

4. The area of principal Doon fan is characterised by gullies of varying dimensions. They have been formed by several factors, such as the nature of the terrain, precipitation and effect of lithology on erosion. The gullies are of two types, viz., continuous and discontinuous. The discontinuous gullies are of sporadic occurrence and are found in terrain with fine textured alluvial fans.

5. The streams reflect more lateral erosion than vertical incision as indicated by the broad channels.

6. The hill torrents constantly change their courses causing an immense damage to the agricultural and forest areas and give rise to stone pavements by removing the soil.

3.2.5 Soils:

Singh and Manchanda (1982) group the soils in Doon Valley to belong to micro and shallow families of Eutrochrepts and Hapludolls in the high mountains, Udorthents and Eutrochrepts in the medium high mountains and Typic Eutrochrepts or the upper piedmont and Typic Hapludolls in the lower piedmont. Bhardwaj and Singh (1981) identified mainly two soil series in the Bainkhala
watershed, viz., the Dhoolkot series and the Bainkhala series. The Dhoolkot series are fine loamy mixed hyper Thermic udic haplustalfs which are non-gravelly, non-calcareous with medium (silty-loam) surface texture and heavy subsoil (silty clay to clay) having iron and manganese concretions. The Bainkhala series are derived from very gravelly recent alluvium and occur as old and new river terraces and flood plains. Taxonomically they are sandy skeletal typic ustifluvents.

3.2.6 Climate:

In general, the climate in the valley is temperate subhumid. The rainfall of this region is characterised by high intensity storms with very high erosion potential (average annual EI_{30} value at Selakui Farm : 1066 (Dhruvanarayana, 1985) the 31 year (1956-86) average annual rainfall is 1676.2 varying between 1265 to 2615 mm (Table 3.2). About 80% of the rainfall occurs in 70 rainy days in the four monsoon months of June to September. A record 24-hour maximum rainfall of 440.4 mm rainfall was recorded at nearby Rajpur in the valley on August 25, 1954 (Gazetteer, 1979) which indicates the magnitude of high rainfall in this tract. On an average, 5.2 bright sunshine hours/day are observed during July and August. May and June are the hottest months with mean maximum temperature going upto 37°C. December and January record lowest temperature of 1°C to 3°C. The extremes of temperatures recorded at the Meteorological Observatory at the Selakui Research Farm of
Table 3.2 Average climatic parameters at Research Farm, Selakui (Dehra Dun)

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<tbody>
<tr>
<td>Total rainfall, mm</td>
<td>1956-86</td>
<td>50.5</td>
<td>45.5</td>
<td>47.1</td>
<td>25.1</td>
<td>39.4</td>
<td>168.6</td>
<td>488.4</td>
<td>500.8</td>
<td>260.1</td>
<td>53.2</td>
<td>24.1</td>
<td>33.7</td>
<td>1676.4</td>
</tr>
<tr>
<td>Max. temp., °C</td>
<td>1962-86</td>
<td>20.0</td>
<td>22.6</td>
<td>28.0</td>
<td>33.6</td>
<td>37.0</td>
<td>36.3</td>
<td>30.6</td>
<td>30.3</td>
<td>31.3</td>
<td>30.0</td>
<td>25.8</td>
<td>21.7</td>
<td>---</td>
</tr>
<tr>
<td>Min. temp., °C</td>
<td>1959-86</td>
<td>3.9</td>
<td>5.8</td>
<td>10.1</td>
<td>13.3</td>
<td>18.2</td>
<td>23.3</td>
<td>24.2</td>
<td>23.8</td>
<td>20.9</td>
<td>14.0</td>
<td>7.4</td>
<td>3.4</td>
<td>---</td>
</tr>
<tr>
<td>Wind velocity, km/hr</td>
<td>1967-86</td>
<td>1.3</td>
<td>1.8</td>
<td>2.1</td>
<td>2.6</td>
<td>2.6</td>
<td>2.1</td>
<td>1.3</td>
<td>1.1</td>
<td>0.9</td>
<td>1.0</td>
<td>1.1</td>
<td>1.1</td>
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</tr>
<tr>
<td>Bright sunshine, hrs</td>
<td>1962-86</td>
<td>7.4</td>
<td>7.6</td>
<td>8.2</td>
<td>9.1</td>
<td>9.8</td>
<td>7.5</td>
<td>5.2</td>
<td>5.1</td>
<td>7.4</td>
<td>9.4</td>
<td>8.5</td>
<td>7.4</td>
<td>2815.3</td>
</tr>
<tr>
<td>Evaporation, mm</td>
<td>1957-86</td>
<td>1.5</td>
<td>2.4</td>
<td>3.9</td>
<td>6.5</td>
<td>8.8</td>
<td>7.0</td>
<td>3.4</td>
<td>2.7</td>
<td>3.1</td>
<td>2.8</td>
<td>1.9</td>
<td>1.4</td>
<td>1381.7</td>
</tr>
<tr>
<td>Solar radiation, Cal/cm²</td>
<td>1978-86</td>
<td>231</td>
<td>298</td>
<td>332.6</td>
<td>479</td>
<td>518.2</td>
<td>442.3</td>
<td>343.7</td>
<td>329.4</td>
<td>391.8</td>
<td>361</td>
<td>330</td>
<td>278.7</td>
<td>---</td>
</tr>
<tr>
<td>Total PET, mm</td>
<td>Average</td>
<td>37.9</td>
<td>55.6</td>
<td>96.6</td>
<td>134.2</td>
<td>168.9</td>
<td>162.1</td>
<td>112.3</td>
<td>102.3</td>
<td>103.5</td>
<td>91.5</td>
<td>52.2</td>
<td>35.3</td>
<td>1152.4</td>
</tr>
</tbody>
</table>

(Source: Tyagi et al. (1988))
the Central Soil and Water Conservation Research and Training Institute, Dehra Dun were 45.5°C on June 15, 1972 and -1.1°C in January, 1971. The valley is also subjected to heavy frost during winter (December to February) which often causes severe damage to crop and tree vegetation. The relative humidity is high during the South-West monsoon, generally exceeding 70 percent on an average.

3.2.7 Natural vegetation:

About 50% of the total area of the Doon Valley lies under forest (Walter., 1911). As per Champion and Seth (1968), broadly the forest vegetation is classified as: (i) Tropical moist deciduous forest, (ii) Low alluvial savannah woodland forest, (iii) Tropical dry deciduous forest, (iv) Dry deciduous forest, and (v) Himalayan moist temperate forest.

Mathur et al. (1982) identified the different tree species to occur in the forests in the following three storeyed way:

Top storey: Sal is the dominant species forming nearly pure stands. Common associate of Sal in the top storey is Terminalia tomentosa.

Middle storey: Grewia elastica, Mallotus philippensis, Machilus oederatissima.

Under growth: Carissa coronda, Murraya koengii, Jasminum perbescens, Dioscorea belephylla.
The following can be stated as the most common trees, shrubs and grasses of the area:

Trees: Shorea robusta, Terminalia tomentosa, Acacia catechu, Cassia fistula, Adina cordifolia.

Shrubs: Lantana camara, Ficus cunia, Zozyphus jujuba, Randia dumatorium.

Grasses: Cynodon dactylon, Chrysopogon fulvus, Heteropogon contortus, Sorghum halepense.

Creeper: Discores sp.

Most of the natural vegetation in the valley is under severe stress due to human influence, particularly due to rapid urbanization and also due to cutting down of forests for fuel wood. Using landsat scenes for the years 1972 and 1982, supplemented by aerial photographs, Sharma and Sharma (1982) have found that the area under closed forests in the Doon Valley has decreased by 32.8% (Fig. 3-3) in the 10-Year period with simultaneous increase in open-forest and non-forest areas by 13.1 and 26.4% respectively during the same period. They have indicated the following as some of the main reasons:

- Over exploitation of forests;
- Illegal clearing for cultivation;
- Excessive grazing; and
- Failure of natural / artificial regeneration.
Fig. 3-3 Change of forest cover in Doon Valley during the period 1972-1982
(Source: Sharma and Sharma, 1982)