CHAPTER II

DRAINAGE CHARACTERISTICS IN THE BASIN

INTRODUCTION

The Balason basin is drained by river Balason and its ten major tributaries and numerous minor tributaries. The basin is funnel shaped with rivers draining from north, northeast, northwest, east and west towards the south. The right bank tributaries are Pulungdung *khola,* Rangbang *nadi,* Marma *nadi,* Manjwa *jhora* and Dudhia *jhora.*The left bank tributaries are Bhim *khola,* Rangmuk *nadi,* Pachhim *nadi,* Rinchingtong *khola* and Ghatta–Hussain *nadi.* All these rivers erode the land and set a typical pattern over the land.

2.1 DRAINAGE CHARACTERISTICS

Entire Balason basin shows a dendritic pattern of drainage. All the streams join each other at acute angles. But along the steep slopes in few areas parallel drainage pattern can also be identified. Parallel drainage pattern shows the structures control over drainage.

2.1.1 Long and Cross Profile

Dudhia jhora has a length of 4.75km. It rises along the Nepal border in the south western part of the study area.

Manjwa jhora, which has a length of 4.1km, originates at an elevation of above 1200m and flows eastwards to meet river Balason at an elevation of 450m.The tributaries at the upper course of the river are almost parallely aligned indicating the presence of steep slope. In the lower course the river has fewer tributaries. Along the long profile there are two sudden changes, one at 1000m and again at 800m.The cross profile at 900m is 'V' shaped. The cross profile at 600m elevation shows steep slope on the left bank whereas right bank has gentle slope. The convex slope of the left bank may be due to the presence of more resistant rocks and less tributaries. In the upper part, the slope of the land is 20° but in the lower part the slope is steep, above 25° (Fig. 2.1).

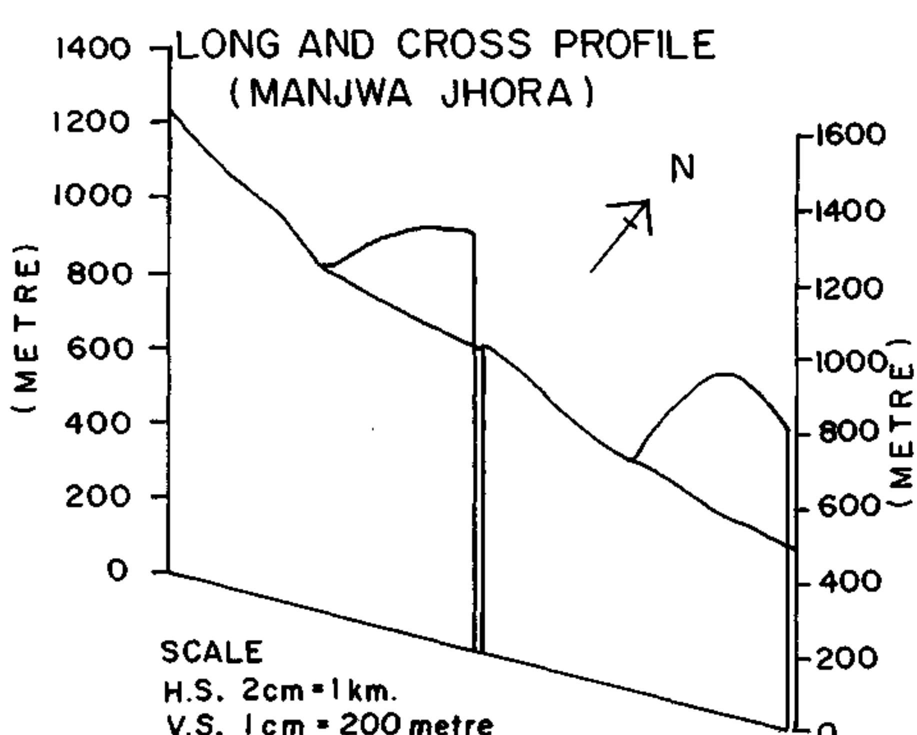
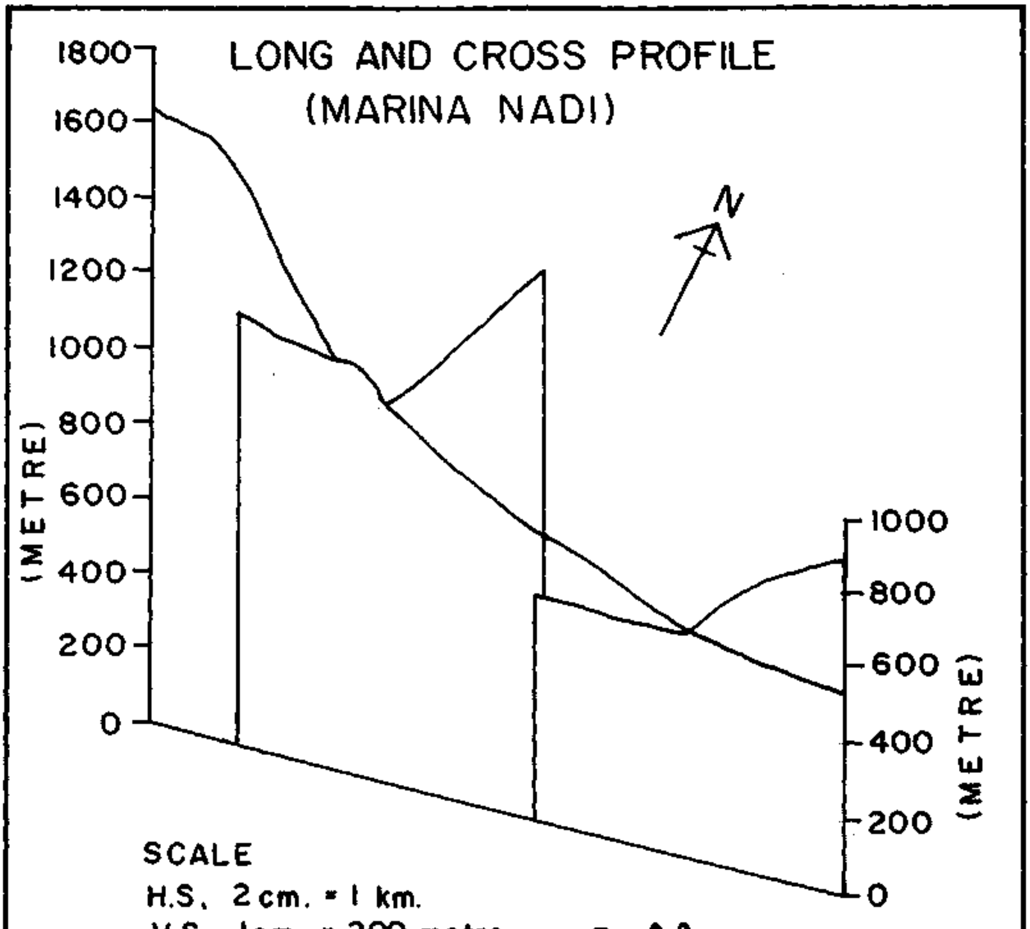

LONG AND CROSS PROFILE
(MANJWA JHORA)
1400
1200
1000
800
600
400
200
0
(METRE)
1600
1400
1200
1000
800
600
400
200
0
(METRE)
N
SCALE
H.S. 2cm = 1 km.
V.S. 1 cm = 200 metre

Fig. 2.1

Marina nadi stretching over a length of 4.25km is slightly longer than Manjwa *jhora*. The course of the river has a typical concave slope. The river rises at an elevation of 1600m, flows eastwards to join river Balason at an elevation of 540m. Under normal circumstances of lithology and structures, weathering and erosion will encourage the formation of concave slope out of a given uniform slope. Gilbert related concavity to water discharge and sediment load. The greater the discharge, the quicker and greater is the transport of load. This would promote concavity. If discharge increased more rapidly down slope than accompanying sediment load, then the whole matter (sediment and load) can be effectively transported even if the slope declined. This would also cause concavity. De la Noe and E. de Margerie(1888) had noted that if weakness of rocks increased upward this would cause the concavity of slopes. Long profile of Marina *nadi* shows the various stages of erosion. At first, the rocks are hard which helps the river to make a convex slope and further down, the river flows through a uniform slope. After flowing 1.5km from the origin, the river flows along a rectilinear slope with declined slope angle. The cross profile at 1000km is peculiar with left bank steeper than the right bank and the right bank is gentle with a sudden break of slope. The cross section at an elevation of 600m shows that the right bank is under continuous erosional process leading to flattish slope. Left bank has harder rock, which is getting eroded at a slower rate than the right bank showing more concavity (Fig. 2.2).

Rangbang nadi extends for a length of 17km. The source lies at a height of 2250m and ends at a height of 525m approximately. Along the long profile of the river, two knick points are visible, one at the height of 1700m and the other further down at an elevation of 900m. The river valley in the upper course that is between the source and 1700m is extremely steep. The angle of steepness or the gradient here is 25°. Between 1700m and 1100m the river has moderate steepness, being 20°- 25°. Between 1100m and 900m the river flows strikingly over a gentle slope making an angle of 20°. At 800m there is a break of slope.


LONG AND CROSS PROFILE
(MARINA NADI)
N
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
1000
800
600
400
200
0
(METRE)
SCALE
H.S. 2 cm. = 1 km.
V.S. 1cm = 200 metre
Fig. 2.2

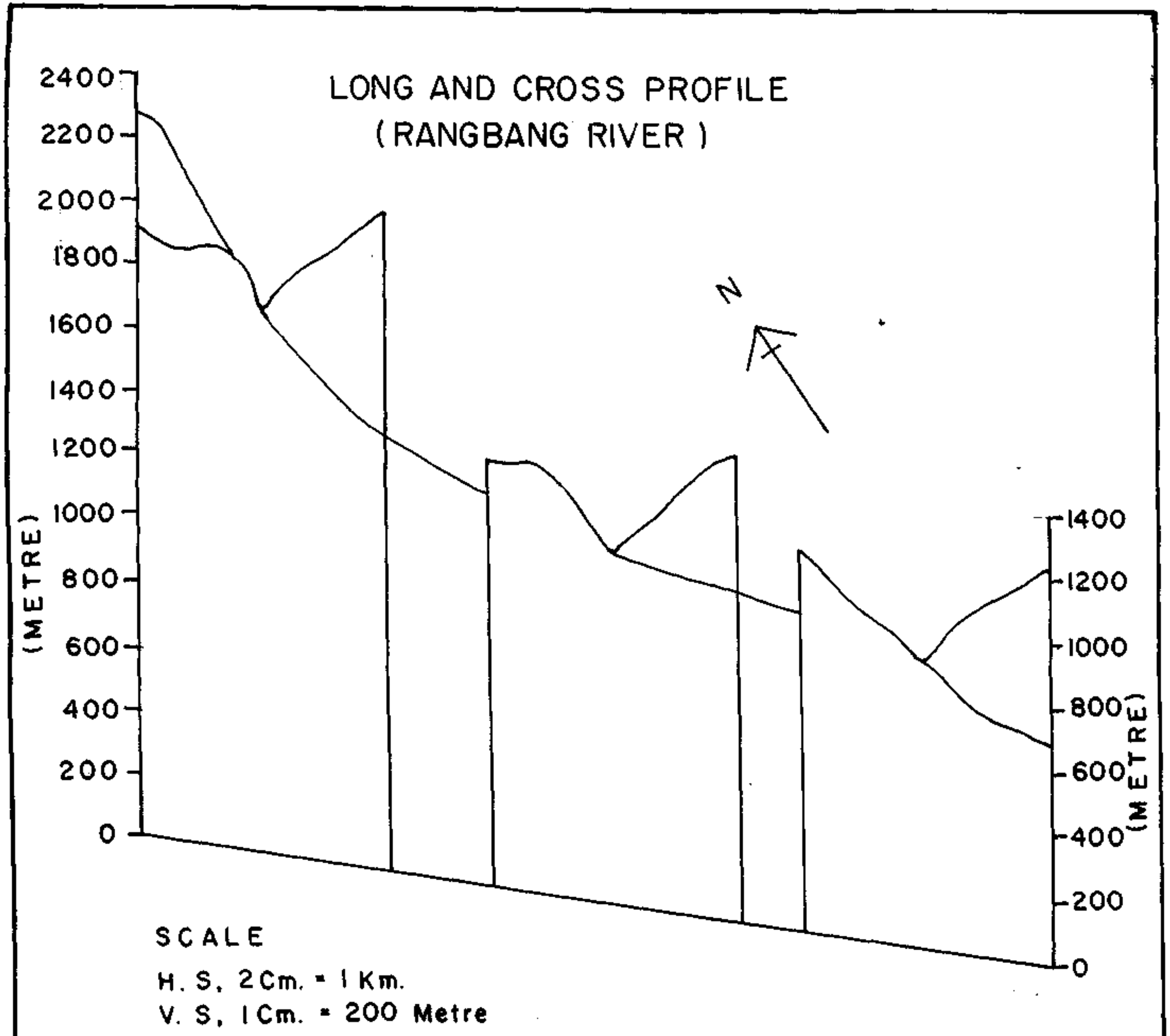

LONG AND CROSS PROFILE
(RANGBANG RIVER)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
N
1400
1200
1000
800
600
400
200
0
(METRE)
SCALE
H. S, 2 Cm. = 1 Km.
V. S, 1 Cm. = 200 Metre

Fig. 2.3

Between 800m and the end point of the river where it meets the mighty Balason approximately at a height of 525m, the Rangbang *nadi* forms a moderately steep slope, similar to the slope between1700m and 1100m. Where the slope is steep, the reason might be the presence of resistant rocks whereas the gentle slopes might result due to the presence of comparatively softer rocks. In the steep slopes there might be probability of flash floods during heavy rain. Gentle and moderate slopes are usually prone to soil erosion and landslides. The cross profiles give a clear idea about the change in the shape of the valley. In the higher altitudes the valley is deep forming narrow 'V' shaped valley. Where the river is flowing at an elevation of 1100m, the 'V' shaped valley is comparatively wider. Around 900m elevation the sides of the river are eroded to a great extent due to lateral corrasion and mass wasting. Thus the valley became much wider. In the last cross section at an elevation of 600m again the 'V' shaped valley became narrow might be due to the local variation of rocks. Below the knick point at an elevation of 900m the river again reached its youth and vertical corrasion has increased forming such a valley (Fig. 2.3).

Phulungdung khola extends for a length of 5.55km. Its source lies at a height of 2150m and joins Balason river at a height of 975m. The long profile of the *khola* shows almost gentle slope except between 1900m and 2000m. Here the slope is slightly steep and the angle of steepness is 15° to 20°. Gentle slope all along the course indicates homogeneous rock structure in the area. The cross profile, where the *khola* is at a height of 1800m is a wider 'V' shaped valley than at a height of 1300m where the valley is comparatively narrow. This might be due to the presence of more resistant rock at the lower elevation (Fig. 2.4).

Bhim khola is one of the longest tributaries of river Balason with a length of 7km. Bhim *khola* originates at a height of about 2100m. Along the long profile a knick point can be observed at a height of 2000m. The slope between 1900m and 2000m is comparatively steep. Further down stream the river slope is gentle. In the upper course, the contours are

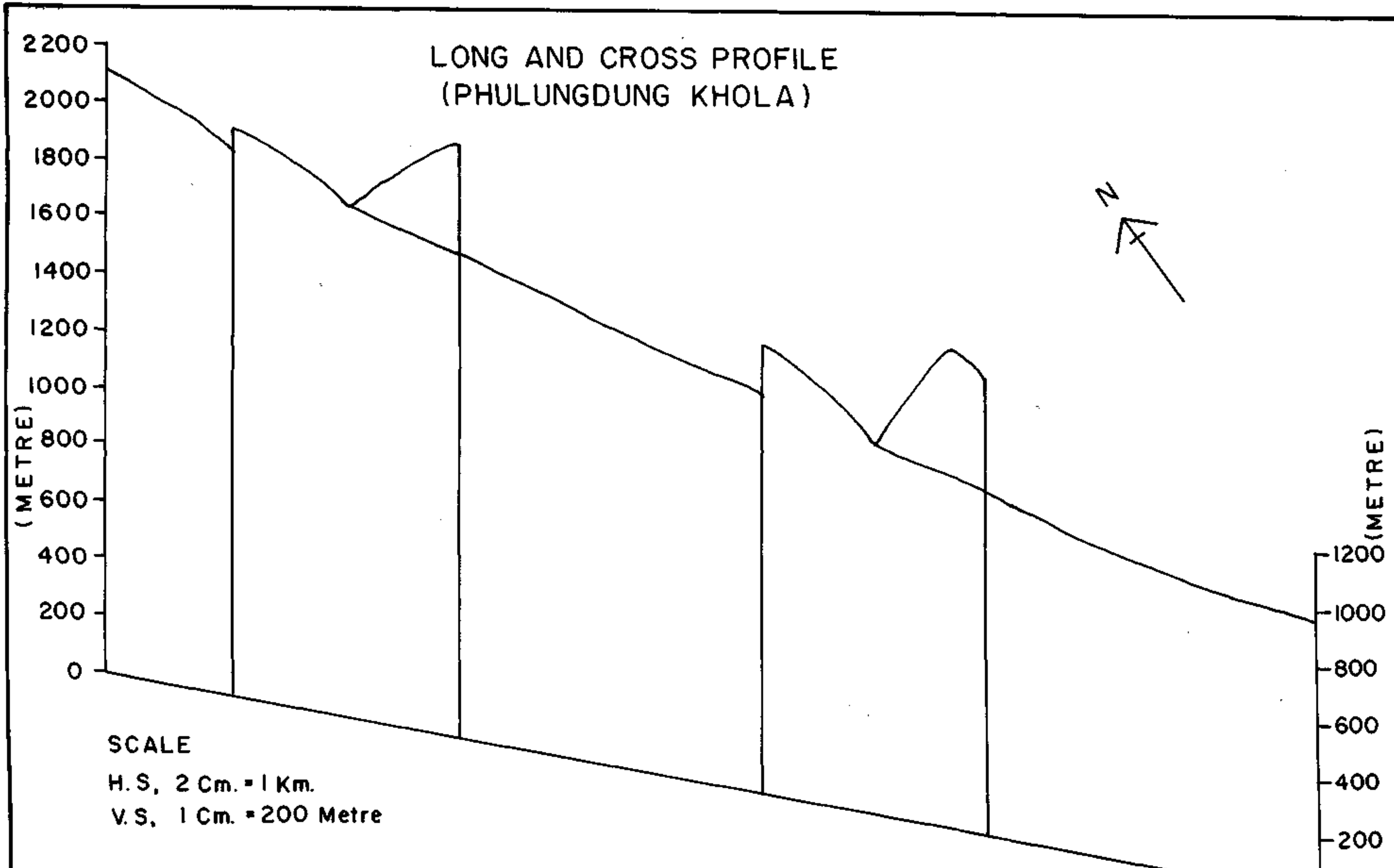

LONG AND CROSS PROFILE
(PHULUNGDUNG KHOLA)
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
N
1200
1000
800
600
400
200
0
(METRE)
SCALE
H.S, 2 Cm. = 1 Km.
V.S, 1 Cm. = 200 Metre

Fig. 2.4

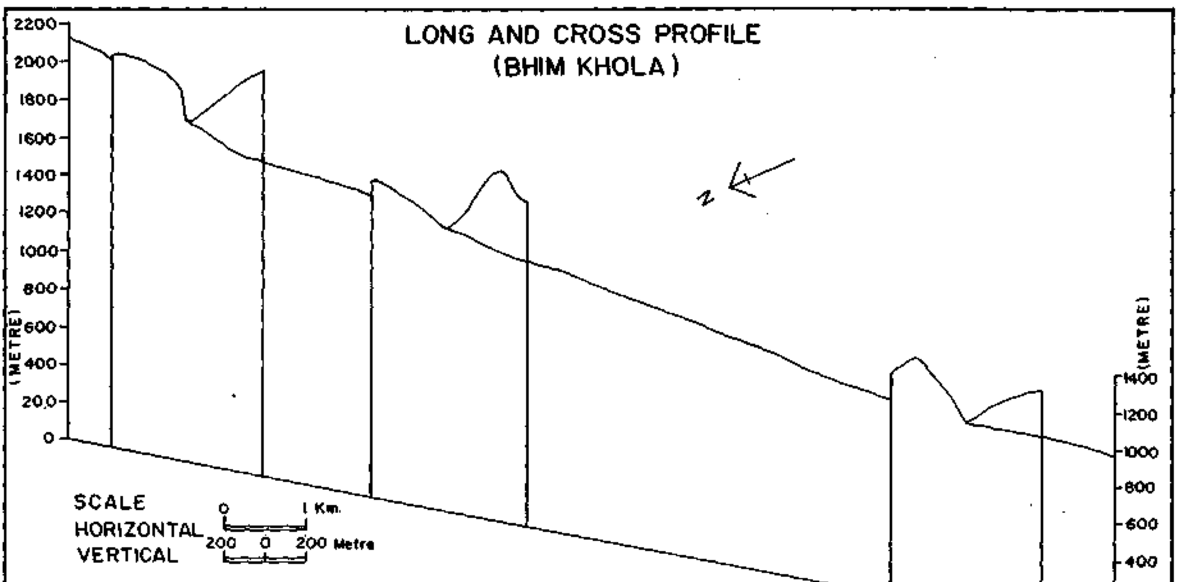

LONG AND CROSS PROFILE
(BHIM KHOLA)
(METRE)
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
1400
1200
1000
800
600
400
200
0
N
SCALE
HORIZONTAL
VERTICAL
0
1 Km.
200
0
200 Metre

Fig. 2.5

closely spaced, middle course contours are moderately spaced and in the lower course contours are sparsely spaced. The slope in the upper, middle and lower part of the river course is 20°, 30° and 25°respectively. The cross profiles give a clear idea about the change in the slope of the valley. Where the river is flowing at a height of 1800m the 'V' shaped valley is extremely steep on the right bank and comparatively gentle on the other side. Further down stream where the river is flowing at a height of 1500m the right bank is extremely eroded may be due to the presence of softer rocks or landslide. The left bank forms a small summit at a height of above 1800m. At about 1000m, the right bank is again steep due to the presence of hard rock and left bank is extremely gentle due to excessive erosion (Fig. 2.5).

Rangmuk nadi rises at a height of 2050m and flows southwards for a distance of 8km, to meet river Balason at an elevation of 800m. Along its course there is sudden break in slope at an elevation of 2000m. From 2000m downwards, the slope is almost vertical. Below the height of 1500m, the slope is quite uniform or rectilinear. Severe down cutting in the upper course of Rangmuk *nadi* leads to the formation of steep slope. The angle of slope is 25°. As we go downstream the angle of steepness decreases. The cross profile at three different heights like 1700m, 1300m and 1000m are 'V' shaped and shows uniformity in the structure of the underlying rocks. Right bank is steeper than the left bank (Fig. 2.6).

Pachhim khola originates at a height of about 1950m and after flowing over a distance of 6.9km meets river Balason at a height of 675m. There are two sudden drops in height, one at an elevation of 1900m and another at 1500m. These two heights might be referred to as knick points. The angle of steepness at 1900m and 1500m are 25° and 20° respectively. Where the river is flowing at a height of 1400m, the valley is narrow 'V' shaped because the *khola* is fast flowing with acute vertical corrasion. At an elevation of 1100m the 'V' shape of the valley has become wider due to lateral erosion. At an elevation of 900m the right bank of the river is completely eroded and lies at a lower

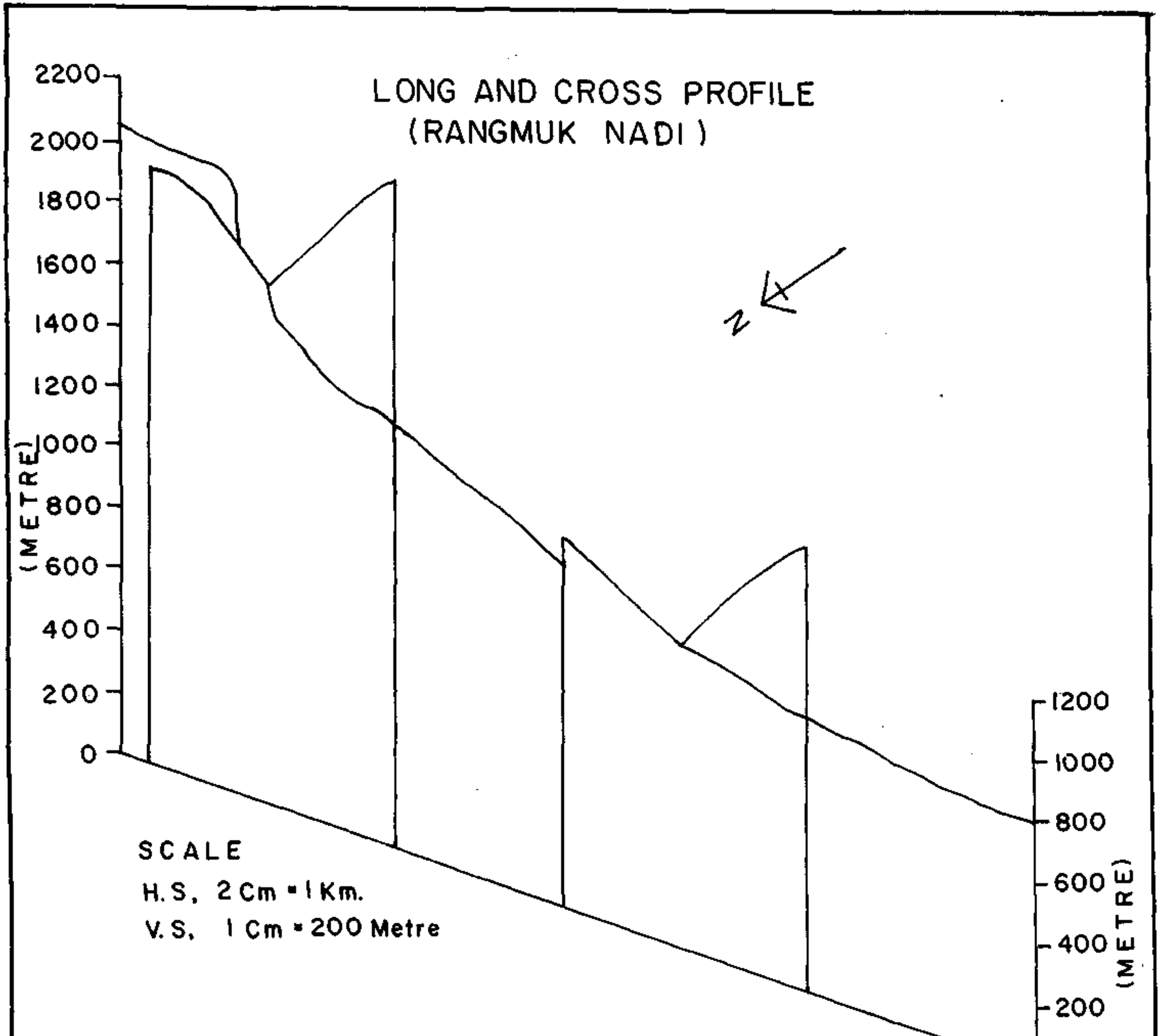

LONG AND CROSS PROFILE
(RANGMUK NADI)
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
N
1200
1000
800
600
400
200
0
(METRE)
SCALE
H.S, 2 Cm = 1 Km.
V.S, 1 Cm = 200 Metre

Fig. 2.6

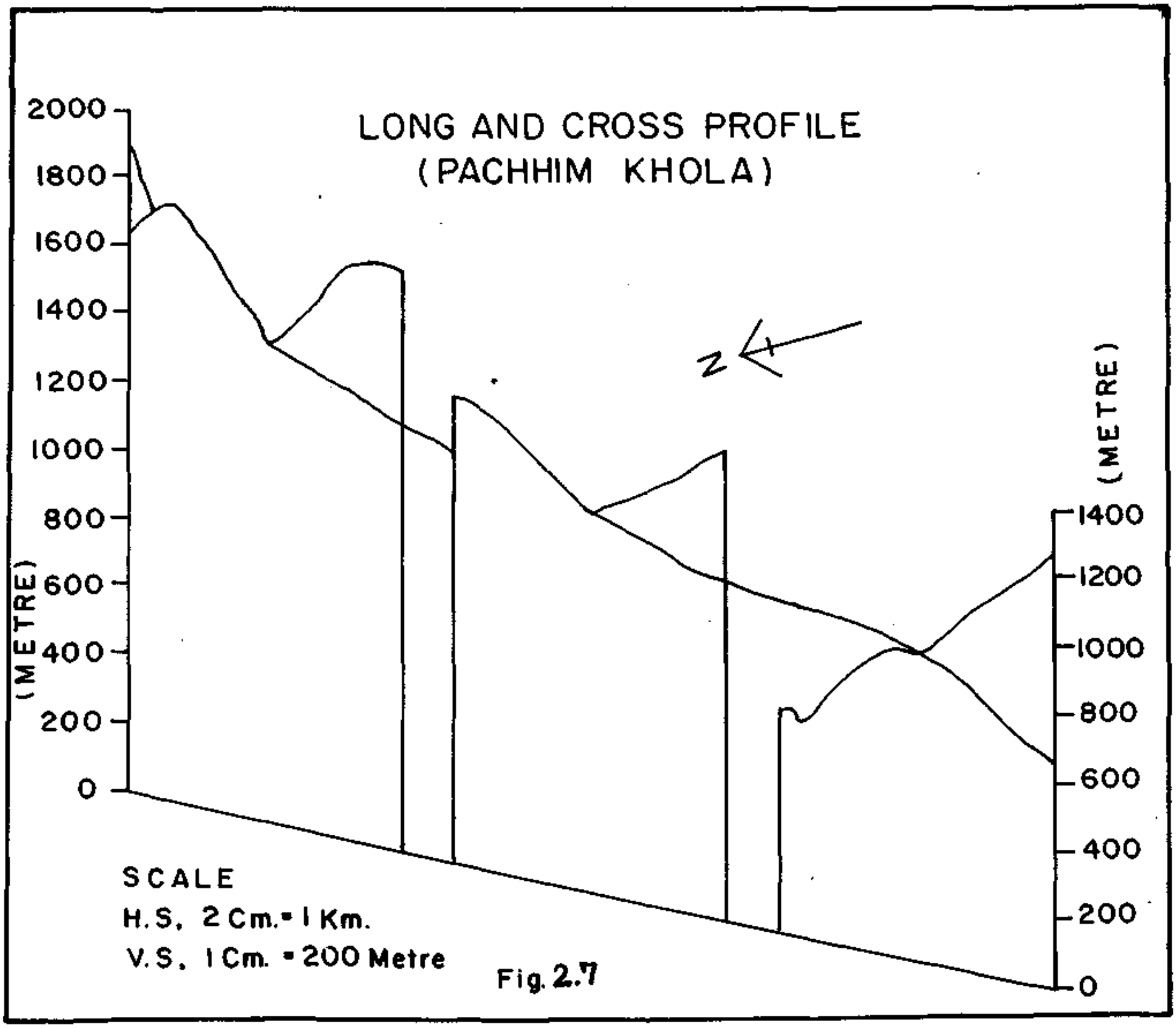

LONG AND CROSS PROFILE
(PACHHIM KHOLA)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
N
(METRE)
1400
1200
1000
800
600
400
200
0
SCALE
H.S, 2 Cm.= 1 Km.
V.S, 1 Cm. = 200 Metre

Fig. 2.7

elevation than the river. On the bank there is an interfluve between the heights of 650m and 900m (Fig. 2.7).

Rinchingtong khola has a length of 7.13km from the source to the point where it meets the Balason river. It rises at an elevation of 1700m and flows southwestwards almost parallel to Rangmuk and Pachhim *khola* in its upper course. Till 1200m elevation, the long profile shows steep slope. Here the slope is also concave and the knick point lies at an elevation of 1200m.Below this, the slope is gentle and at the end it is convex in shape. In the three cross profiles at heights 1500m, 1200m and 700m, the left banks are steeper than the right banks in the upper course (Fig. 2.8).

2.1.2. Stream Ordering

Rivers like Dudhia *jhora,* Marina *nadi,* Phulungdung *khola,* Bhim *khola* and Pachhim *khola* has only till third order streams.Other rivers like Manjwa *jhora,* Rangbang *nadi,* Rangmuk *nadi,* Rinchington *khola* and Ghatta – Hussain *nadi* has till fourth order streams. The three rivers namely Dudhia *jhora,* Manjwa *jhora* and Marina *nadi* which drains almost same area of land, Dudhia has the largest number of first order streams which indicated more erosion. The next four rivers, which drain almost the same area of land, are Phulungdung *khola,* Pachhim *khola,* Rinchington *khola* and Ghatta- Hussain *nadi.* Rinchington has the largest number of first order streams (Fig. 2.9).

Among all the tributaries of Balason river, Rangbang *nadi* has the highest number of first order streams with maximum dissected valleys. Rangbang flows through a valley with slope ranging between 20^0 and 25^0. In the upper reaches the drainage density is high indicating massive erosion of the rock along the hill slopes. So, Rangbang basin is likely to have more flood peaks. In the entire Balason basin, first order streams are almost five times more than the second order streams. This indicates that the entire basin is prone to severe soil erosion.

2.1.3. Drainage Frequency

Balason basin has been divided into five drainage frequency regions. Very low drainage frequency is found in the northern part of

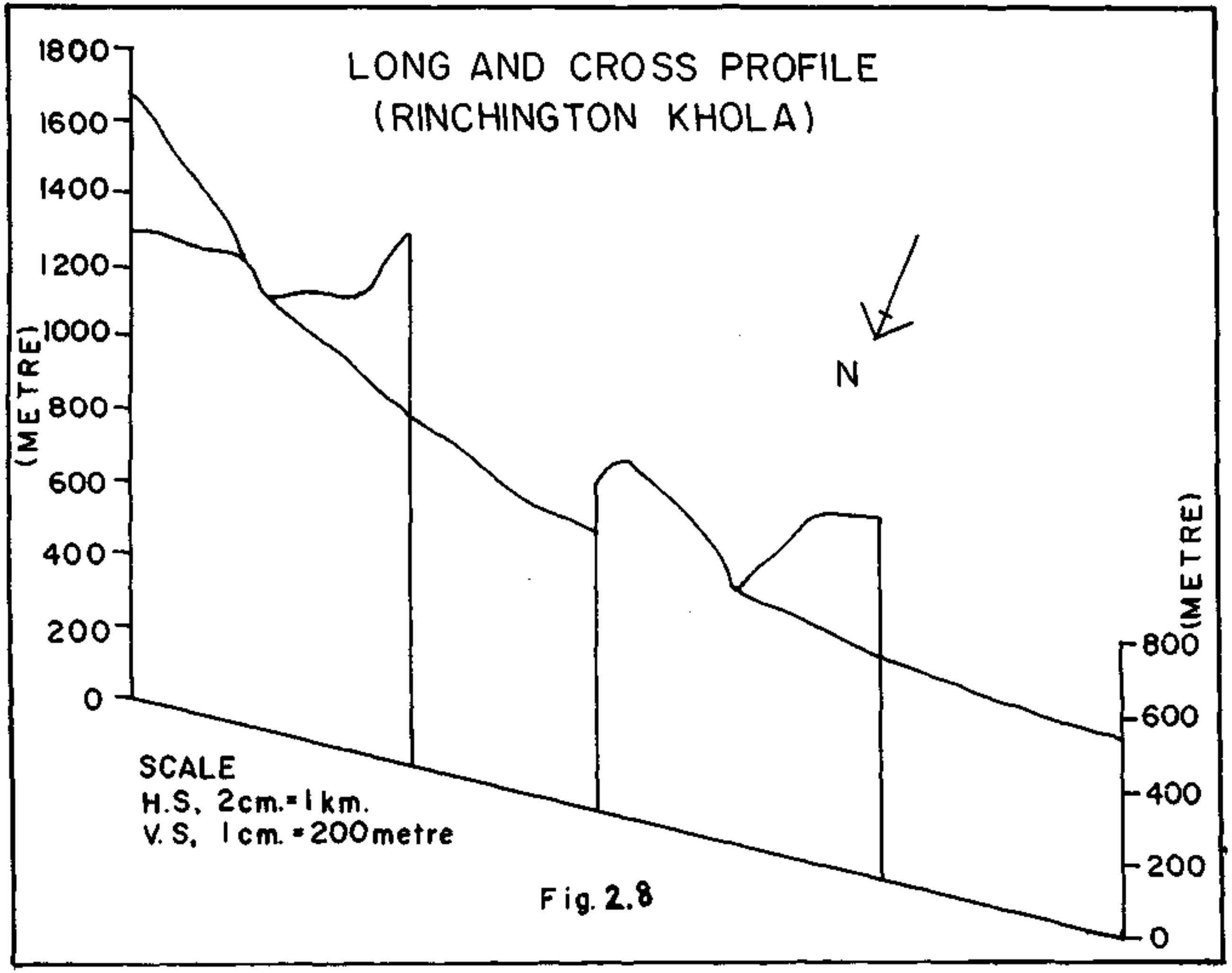

LONG AND CROSS PROFILE
(RINCHINGTON KHOLA)
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
N
SCALE
H.S, 2cm.=1km.
V.S, 1cm.=200metre
800
600
400
200
0
(METRE)

Fig. 2.8

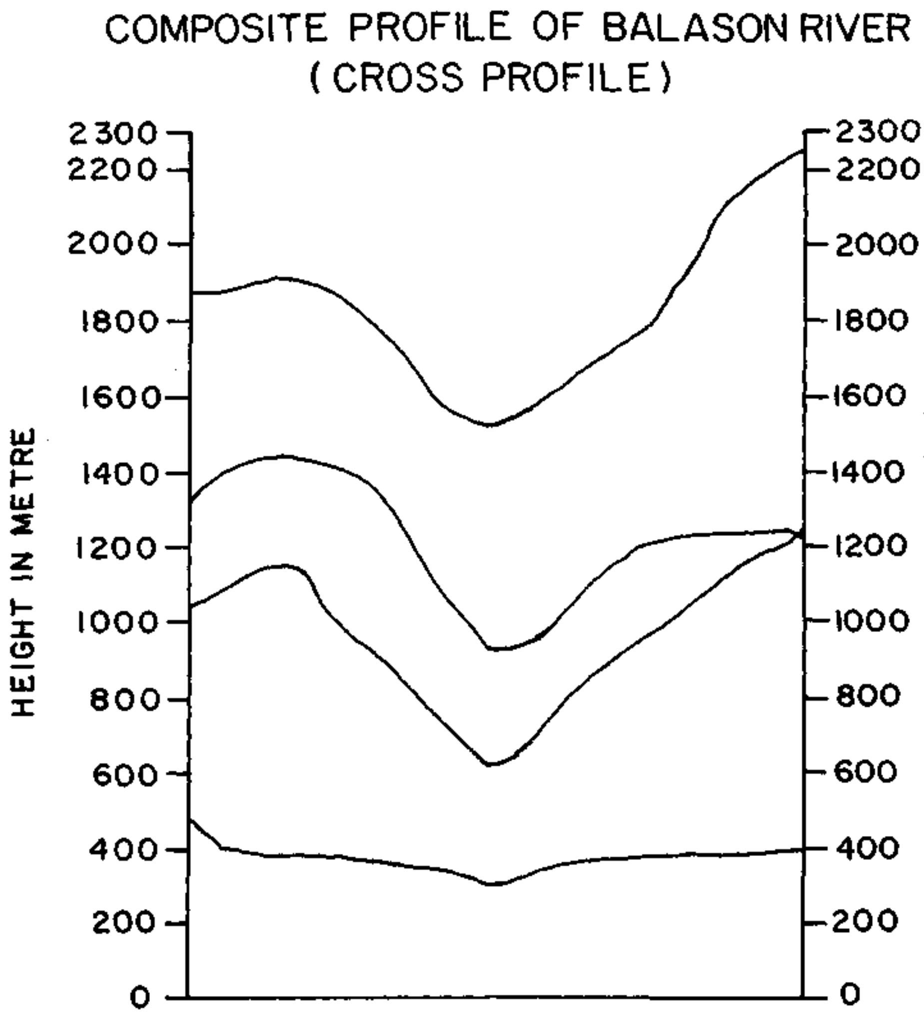

COMPOSITE PROFILE OF BALASON RIVER
(CROSS PROFILE)
HEIGHT IN METRE
HEIGHT IN METRE
2300
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0

Fig. 2.8a

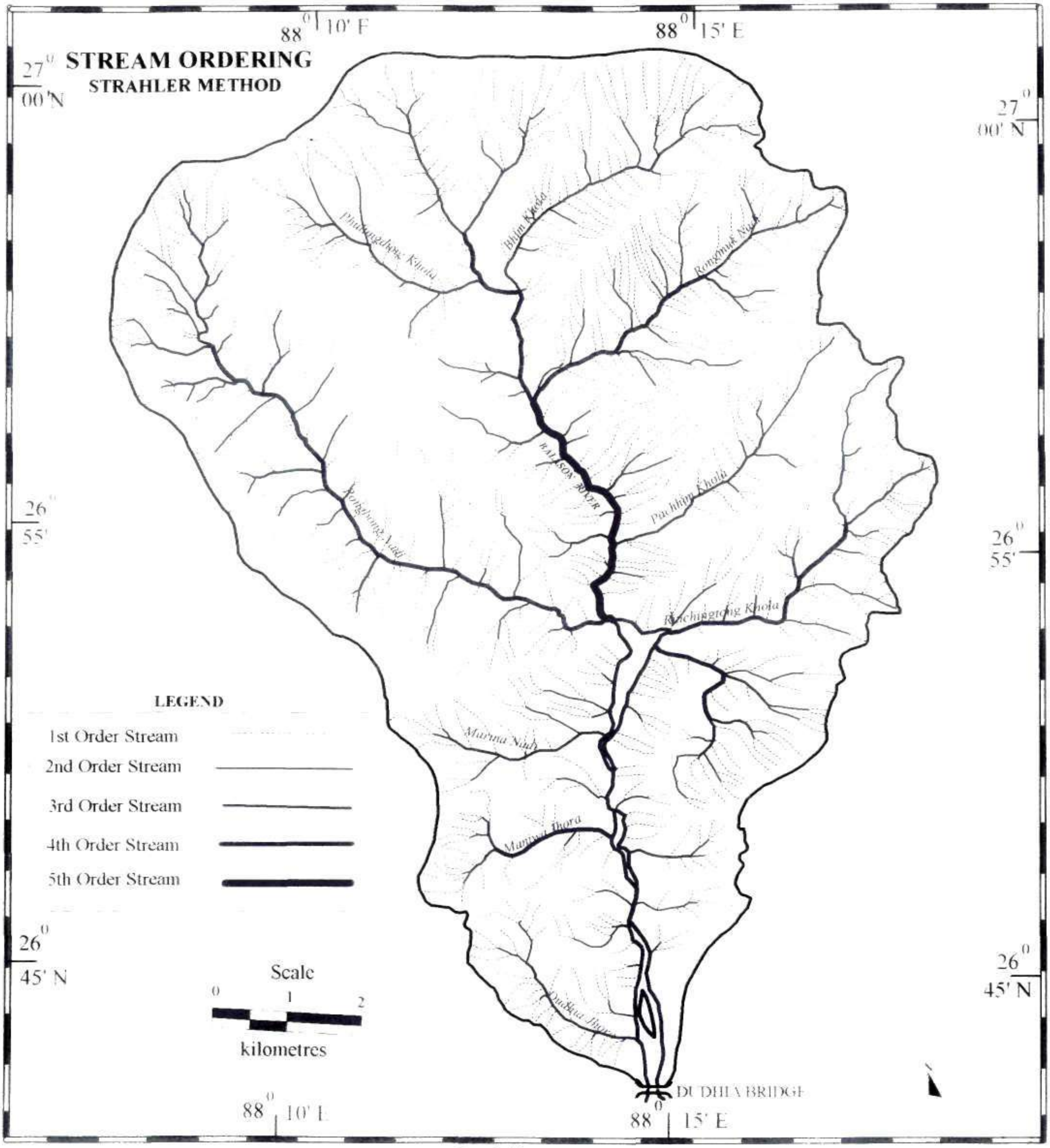

STREAM ORDERING
STRAHLER METHOD
88° 10' E
88° 15' E
27° 00' N
26° 55'
26° 45' N
Phulungdhong Khola
Bhim Khola
Rongmuk Nadi
BALASON RIVER
Pachhim Khola
Ronghong Nadi
Rachingtong Khola
Marma Nadi
Manjwa Jhora
Dudhia Jhora
DUDHIA BRIDGE
LEGEND
1st Order Stream
2nd Order Stream
3rd Order Stream
4th Order Stream
5th Order Stream
Scale
0
1
2
kilometres

Fig. 2.9

the basin along the Jorebunglow – Sukhiapokhri ridge. Other areas are found as small isolated pockets. Medium drainage frequency i.e. 6 to 8 streams per km^2 dominates maximum area of the Balason basin. High drainage frequency areas are coinciding with high relative relief areas. Very high drainage frequency areas are restricted to certain areas only in the northeastern corner of the map (Fig. 2.10).

2.1.4. Drainage Density

The drainage density of any particular area is a function of geologic structure and climatic factors, specially, rainfall. A drainage network of specific pattern and density develops on account of the fact that streams always seek out and take advantage of weakness in the rock strata over which they flow. They provide useful clues about land stability and in turn, important clues about feasibility of certain land management practices (Hornbeck, 1984). The drainage density could be assessed for the entire basin or can also be assessed for a specified stream order where it will represent length of all channels above the specified stream order, per unit of drainage area (Langbein, 1975). High drainage density affects run off pattern. A high drainage density moves surface water rapidly decreasing the lag time and increasing the peak of hydrograph (Singh et la, 1991). In other words, higher the drainage density, more efficient is the drainage and more flashy is the stream flow and vice versa (Varshney, 1971). The drainage density has an important bearing on transport of eroded material. Higher the drainage density, higher is the sediment delivery ratio (Oyebande, 1981). The values of sediment delivery ratios vary as widely as 5% - 100% (Chow, 1964). The drainage density exhibits a wide range of values in nature and varies from 3 – 4 to as high as 1300 (Chorley, 1971). In areas having comparable rainfall pattern it is a function of permeability of the soil mantle. The sandy soils shall show the least values and the impermeable clays the highest (Fig. 2.11).

The drainage density in the study area varies from 4.0 to 10.0km per km^2. The drainage density is high along the ridge areas where the relative relief is moderate. This may be due to the presence of hard

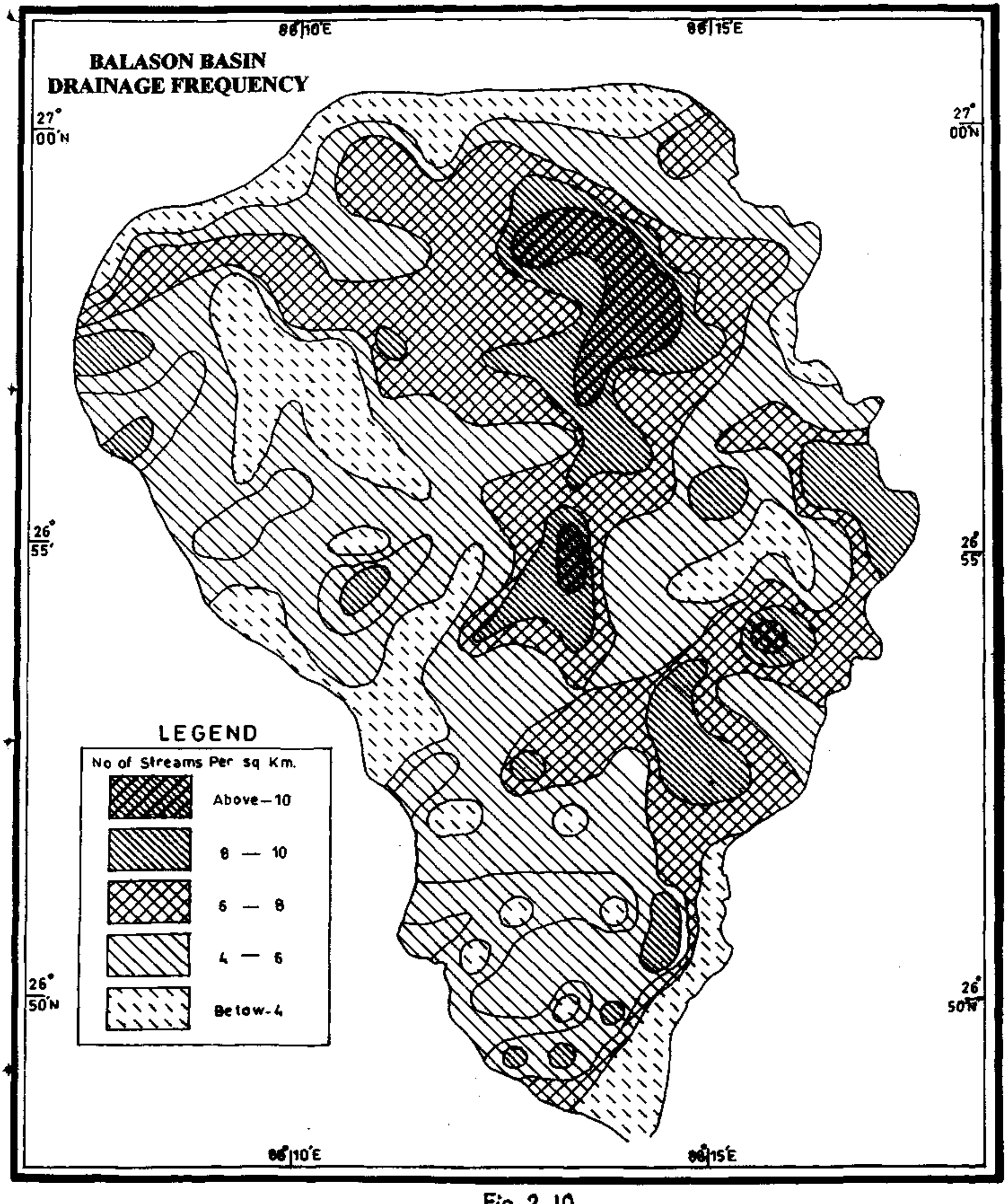
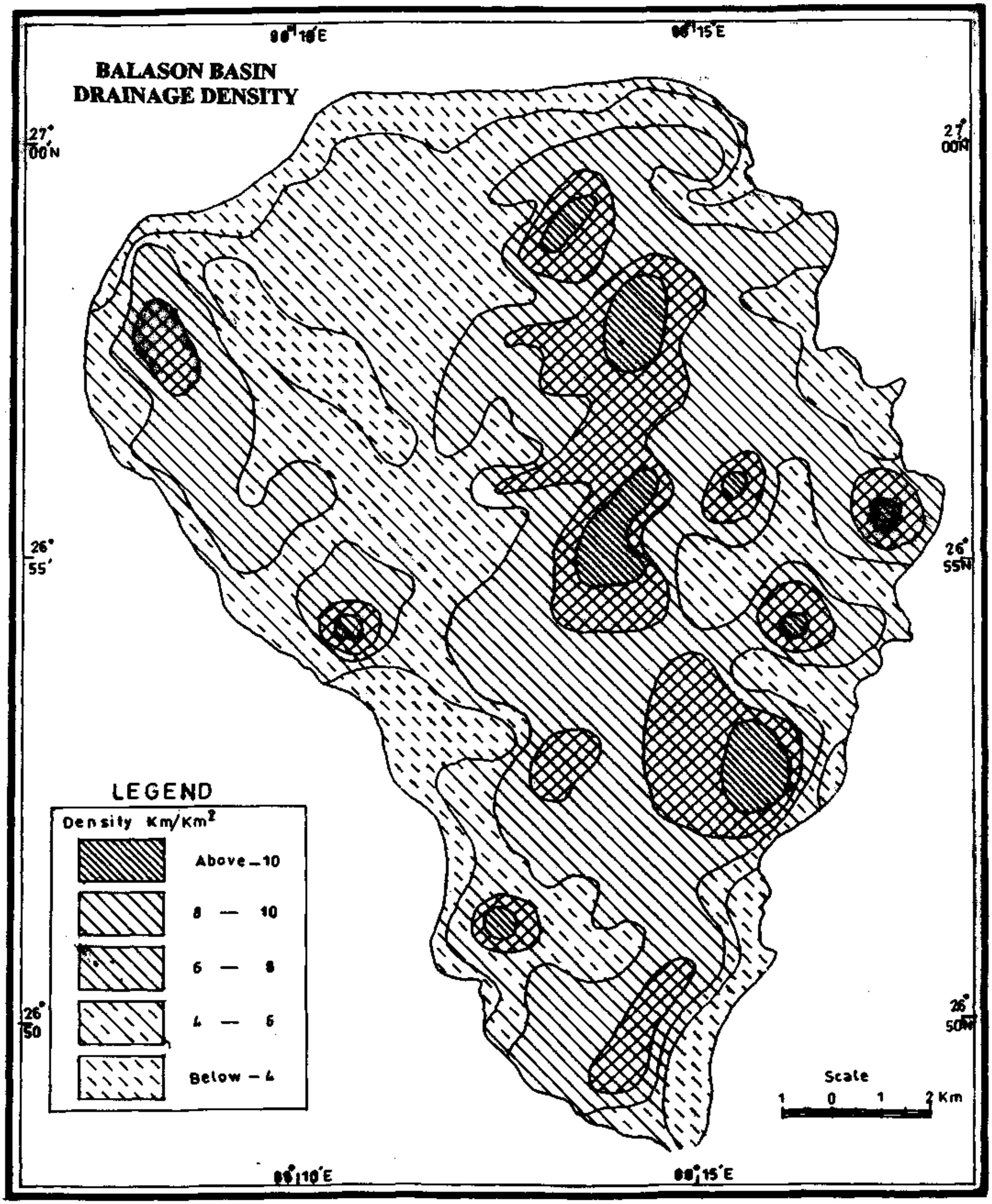

BALASON BASIN
DRAINAGE FREQUENCY
86°10'E
86°15'E
27°
00'N
26°
55'
26°
50'N
LEGEND
No of Streams Per sq Km.
Above – 10
8 — 10
6 — 8
4 — 6
Below - 4

Fig. 2.10



BALASON BASIN
DRAINAGE DENSITY
88°10'E
88°15'E
27° 00'N
26° 55'N
26° 50'N
LEGEND
Density Km/Km²
Above - 10
8 — 10
6 — 8
4 — 6
Below - 4
Scale
1 0 1 2 Km

Fig. 2.11

rock. The small streams are unable to cut the hard rock. Only rills can be formed. Drainage density is high in the middle and lower part of the rivers and these are the places of moderate to low relative relief. The areas of high drainage density are located in Thurbo T.G. in the west, Tongsong and Rangmuk T.G. in the north, Dilaram, Ringtong and Ambootia T.G. in the east, Mondakoti, Dhajea and Phulbari T.G. in the center and Phuguri T.G. in the south. All these areas have drainage density above 10.0km per km^2 and are found in small isolated pockets. Maximum area of the basin falls under 6.0 to 8.0 km per km^2 drainage density region, which shows moderate density. Along the western part of the basin, tea gardens, which lie in this area, are Chamu, Seyok and Marma. Along the eastern part lie Talkat and Okas T.G. In the water divide between Rangbang and Phlungdung *nadi*, the relative relief is moderate but drainage density is very low. This indicates less down cutting power of the small first order streams. Lowest drainage density is below 4km per km^2, which is also found in the southern most part of the basin.

2.1.5. Bifurcation Ratio

The bifurcation ratio of the ten sub – basins of river Balason, ranges from 2.9 to 7.3. The higher the bifurcation ratio, the younger is the drainage. So Bhim *khola* (rb = 7.3) is younger compared to Manjwa *jhora* (rb = 2.9). Bifurcation ratio above 3 usually indicates that the river is prone to floods. The hydrograph of Manjwa basin is therefore, the most acute and that for Bhim is flattest of all. The bifurcation ratio of the entire Balason basin is 5.2, which shows that the area is prone to floods. The determination of bifurcation ratio of basins has been done following standard techniques (Chorley, 1971).

2.1.6. Circularity Ratio

In circularity ratio, value ranges from 0 to 1. Values above 0.5 indicate maturity of the river basin in its evolutionary cycle. Circularity ratio of Rangbang *nadi* and Phulungdung *khola* is high ranging from 0.5 to 0.6 whereas that of Manjwa jhora, Bhim khola, Rangmuk nadi and Ghatta – Hussain *nadi* ranges from 0.6 to 0.7. Basins of

Rinchington *khola*, Dudhia *jhora*, Marina *nadi* and Pachhim *khola* have circularity ratio below 0.5 which indicates that the rivers are in their youthful stage, eroding more by vertical corrasion.

Table: 2.1 Morphometric characteristics of the major rivers in the basin.

Name of sub-watershade	Bifurcation Ratio	Circularity Ratio+	Elongation Ratio#	Form Factor*	Compactness Co-efficient
Dudhia *Jhora*	4.9	0.48	0.61	0.75	1.44
Manjwa *Jhora*	2.9	0.68	0.70	0.73	1.22
Marina *Nadi*	4.3	0.48	0.63	0.81	1.44
Rangbang *Nadi*	5.4	0.57	0.61	0.30	1.32
Phulungdung *Khola*	5.8	0.55	0.71	0.46	1.34
Bhim *Khola*	7.3	0.66	0.73	0.47	1.23
Ramgmuk *Nadi*	4.4	0.66	0.65	0.40	1.23
Pachhim *Khola*	5.7	0.49	0.54	0.70	1.43
Rinchingtong *Khola*	4.3	0.37	0.54	0.65	1.64

*(*Horton1932, +Miller1953, #Schumm1956)*

2.1.7. Elongation Ratio

Lower the value of elongation ratio, the basin is more elongated which means that the basin is structurally controlled and relatively in a youthful stage and hence more prone to erosion (Mithra & Rao, 1993). In the Balason basin in case of both Pachhim and Rinchingtong *khola,* elongation ratio is 0.54, which is less compared to 9.2 of Ghatta – Hussain *nadi.* So soil erosion caused by Ghatta – Hussain *nadi* is less since it's in its mature stage. Both Pachhim and Rinchingtong are in their youth and so these rivers more effectively do soil removal.

2.1.8. Form Factor

This is the shape index of the basin. Form factor is highest (0.81) in Marina *nadi* and lowest (0.30) in Rangbang *nadi.* So the shape of the Rangbang basin is more elongated than the Marina basin.

2.1.9. Compactness Co-efficient

Compactness co-efficient is highest (1.64) in Rinchingtong Khola and lowest (1.22) in Manjwa jhora. If this value is greater than one, it indicates that the basin in compact in nature. All the tributaries of river

Balason flows through compact basins.

CONCLUSION

River Balason flows from north (Lepcha Jagat) to south. Among the ten major tributaries, which spread over the basin, Marina, Rangbang and Rangmuk are perennial. Rivers like Rangbang, Phulungdung and Rangmuk rises at an elevation of above 2000m. All the rivers flow through deep and precipitous gorges in their upper course. Long profile of the rivers show concave and rectilinear pattern of slopes. The cross profiles are different in case of different rivers. In Marina *nadi* and Rinchingtong *khola*, the left banks are steeper whereas in Bhim and Rangmuk *nadi*, the right banks are steeper. The rivers through gentle slope indicating homogenous rock structure in the area. The study area has mainly dendritic drainage pattern accompanied by parallel drainage pattern wherever the land is very steep and this indicates structural control over drainage. In the entire basin, as usual, the number of first order streams is more than the other ordered streams. Rangbang *nadi* has the largest number of first order streams with maximum dissected valleys. The study area is dominated by medium frequency (6 to 8 streams per km^2). High drainage frequency areas have high relative relief. The drainage density in the study area varies from 4 to10km per km^2. The drainage density is high along the ridge areas where the relative relief is moderate. Maximum part of the basin has medium drainage density (6 to 8 km per km^2). Lowest drainage density, below 4km per km^2 is found in the southern part of the study area. Bifurcation ratio of the entire basin is 5.2, which indicates high flood peak. Circularity ratio of six tributary rivers is above 0.5, whereas rest tributary rivers have circularity ratio below 0.5. Elongation ratio and form factor both confirm the elongated shape of majority of the tributary basins. All the tributary drainage systems are compact in the study area. The settlements depend on the availability of water so generally population lives on the bank of river or valley of the river. Availability of water has greatly influenced the spread and growth of population. The study area is mountainous with fast flowing rivers. So distribution of settlements and growth of population with their demographic characteristics can be discussed in the next chapter.