CHAPTER VI

THE WATER RESOURCE : PROBLEMS & PROSPECTS

6.1 INTRODUCTION

The Kurseong Sub-Division of Darjeeling Himalaya is unable to hold back water due to extensive deforestation and commercialisation of hill slopes, as a result, most of the precipitated water goes down the slope, giving rise to severe soil erosion landslides. The river channels, especially in its lower section is virtually incompetent to cope with such enormous amount of debris received from the upper catchment. The riverbeds are thus gradually elevated, restricting the free passage to an excessive amount of run-off, which follows heavy and concentrated rainfall and cause flood. The picture is just opposite during the non-monsoon months when the paucity of water hinders the local people from reaping any benefit out of soil, in conjunction with the river itself (Sarkar, 1989). The overall economic situation of the area concerned is thus, becoming bleaker day by day. In the absence of suitable facilities, the vast quantity of monsoon supplies run waste and the problem of proper scientific management of water redistribution during the drought, needs an immediate and closer investigation.

The aim of this chapter is to assess the annual water resource of Kurseong Sub-Division, its seasonal distribution, its present utilisation and conservation. The investigator, therefore, concentrates his investigation on:

- the study of rainfall and run-off,
- the study of evaporation,
- estimation of water resources,
- the study of discharge and silt load of the major rivers, and
- the problem of the conservation of water resources.

6.2 STUDY OF RAINFALL AND RUN-OFF

According to Khosla (1950), the run-off is the function of precipitation and temperature, i.e.,

$$R \,\alpha\, P/T \text{ ....6.1}$$

Where R = run-off, P = precipitation after the deduction of losses and T = temperature. The common loss due to evaporation and transpiration, generally known as evapotranspiration, is the function of temperature of the area concerned. Thus Khosla's formula reads as follows:

$$R_m = P_m\text{-}L_m \text{ ....6.2}$$

Where, R_m = monthly run-off, P_m = monthly precipitation and L_m = monthly evaporation loss.

Again the amount of monthly evaporation loss (L_m) is given as:

$$L_m = T_m{}^{o}C/0.2074 \text{ ....6.3}$$

For determining the evaporation loss and the resulted run-off following the Khosla's model, the investigator has obtained the average monthly rainfall data from various recording stations, mostly from the Tea Gardens and Forest Directorate. While, in the case of temperature, the author has mostly depended on the interpolation and extrapolation of isotherms due to the lack of adequate temperature recording stations. The Table 6.1 shows the distribution of average rainfall, temperature, evaporation loss and run-off in each of the stations individually for the period of last 25 to 90 years. After careful analysis, it reveals some interesting results, like some pre-monsoon rainstorms during March-May, yield a considerable amount of run-off in the north-central part of the study area i.e., Mahaldiram, Divisional Forest Office, Dow Hill, Victoria School. This area records a relatively high amount of run-off, ranging between 40 to 70% of the total rainfall, during April-May. This is most probably due to low prevailing temperature, which causes lower amount of evaporation loss. The stations along the eastern part, south central and south-western part, yield comparatively a lower amount of run-off varying from 25 to 40% of the total rainfall during the pre-monsoon months. While the foothills and the southern margin of the study area show moderate run-off which vary from 40 to 50% of the total rainfall during May.

Table 6.1

Hydro-Meteorological Parameters of Different Recording Stations (Mean Annual)

Sl.No.	Station	Altitude (m)	MaP (mm)	MaT (°C)	MaE (mm)	Evaporation loss as % of Map	Total Run-off in mm	Run-off % of MaP
1	DFO Dow Hill	1769	4654.8	14.88	861.09	18.5	3793.4	81.49
2	Mahildaram TG	1676	4879.3	15.53	898.41	18.34	3998.9	81.66
3	Victoria School	1829	4257.9	14.37	831.53	19.53	3426.7	80.47
4	Latpanchor	1143	4030	18.71	1082.55	26.86	2947.6	73.14
5	Sittong CP	1372	2833	19.31	1117.38	39.44	1715.6	60.56
6	Goomtee TG	1290	3740.7	19.88	1150.13	30.75	2590.1	69.25
7	Tindharia TG	720	2964.5	31.81	1204.3	40.62	1760.2	59.38
8	Jogmaya TG	800	3371.9	20.72	1198.61	35.55	2173.3	64.45
9	Sepoydhura TG	600	3540.2	21.33	1234.06	34.86	2306.1	65.14
10	Sukna RS	163	3868.9	23.57	1363.43	35.24	2505.5	64.76
11	Gulma TG	122	3984	23.71	1371.54	34.43	2612.5	65.57
12	Salbari ARO	136	3513.4	23.91	1383.51	39.38	2129.9	60.62
13	Siliguri		3623.5	24.63	1425.3	39.33	2198.2	60.67
14	Bagdogra	131	2318	23.96	1386.56	59.81	931.8	40.19
15	Longview TG	610	4080.9	21.17	1224.58	28.61	3056.3	71.39
16	Pankhabari RO	564	3511.9	21.33	1234.29	35.15	2277.6	64.85
17	Mongpu CP	1200	3131.4	15.53	892.52	28.5	2238.9	71.5
18	Fuguri TG	782	2901.5	20.03	1158.9	39.94	1742.6	60.06
19	Saureni TG	623	2841.3	21.05	1218	42.87	1623.3	57.13
20	Manjha TG	510	3121	22.03	1275	40.85	1845	59.15
21	Ambutia TG	948	4915	19.73	1142	23.23	3773	78.77
22	Gayabari TG	849	3945	20.13	1165	29.53	2780	70.47
23	Makaibari TG	1030	4516.1	18.5	1070	23.69	3446.1	76.31
24	Castleton TG	1140	4623.3	18.41	1065	23.04	3558.3	76.96
25	Spring Field TG	970	4370.8	18.91	1094	25.03	3276.8	74.97
26	Bamanpokhri RO	390	3943.1	13.15	1339	33.96	2604.1	66.04
27	Simulbari TG	350	3242	23.01	1331.3	41.06	1910.7	58.94
28	Singeli TG	1020	3093.1	19.13	1107.1	35.79	3081.39	64.21
29	Thurbo TG	1451	2431	15.01	868.5	35.73	1562.5	64.27
30	Okayti TG	1840	2349.5	13.9	804.3	34.23	1545.2	65.77

DFO: Divisional Forest Office; TG: Tea Garden; CP: Cinchona Plantation; ARO: Agriculture Research Station; RO: Range Office; MO: Meteorological Office; MaP: Mean Annual Precipitation; MaE: Mean Annual Evaporation loss; MaT: Mean Annual Temperature.

With the beginning of the heavy rainstorms (monsoon) in the month of June, the amount of run-off as percentage to the total monthly rainfall shoots upto over 90% along the southern margin of the Mahaldiram range, around Kurseong, Ambutia, Makaibari, Springside Tea

Gardens. The amount varies in between 80 to 90% along the southern margin of the study area i.e., Sukna, Pankhabari, Salbari, Gulma area in between 70 to 80% in the east-central, west-central and along the central parts of the study area.

Table 6.2

Hydro-Meteorological Parameters of Different Recording Stations (Monsoon)

Sl. No	Station	MmP (mm)	MmT (°C)	MmE (mm)	Mme as % of MmP	TmR (mm)	TmR as % of Map
1	DFO Dow Hill	4076.1	18.2	445.04	10.92	3631.06	89.08
2	Mahildaram TG	4238.3	19.4	459.74	10.85	3778.56	89.15
3	Victoria School	3787.6	21.3	434.52	11.47	3353.08	88.53
4	Latpanchor	3460.1	22.9	518.51	14.99	2941.59	85.01
5	Sittong CP	2381.8	23.2	539.3	22.64	1842.5	77.36
6	Goomtee TG	3271.1	24.3	553.47	16.92	2717.63	83.08
7	Tindharia TG	2700.4	24.7	586.26	21.71	2116.14	78.36
8	Jogmaya TG	2879	25.4	584.97	20.32	2294.03	79.68
9	Sepoydhura TG	3321.7	27.3	600.48	18.08	2721.22	81.92
10	Sukna RS	3535.1	27.8	654.44	18.51	2880.66	81.49
11	Gulma TG	3487	27.8	656.95	18.84	2830.05	81.16
12	Salbari ARO	3023	27.9	663.02	21.03	2492.3	78.97
13	Siliguri	3156	27.5	663.7	21.03	2492.3	78.97
14	Bagdogra	1949.1	24.9	663.7	34.10	1282.4	65.90
15	Longview TG	3824.7	24.8	598.69	15.65	3226.01	84.35
16	Pankhabari RO	3097.6	19.3	597.88	19.30	2499.72	80.70
17	Mongpu CP	2508.6	24.3	458.49	17.92	2050.11	82.08
18	Fuguri TG	2525.1	24.9	585.8	23.20	1939.3	76.80
19	Saureni TG	2491	25.3	600.3	24.10	1890.7	75.90
20	Manjha TG	2643.1	24.2	609.9	23.08	2033.2	76.92
21	Ambutia TG	4371.5	24.6	5861.1	13.41	3785.4	86.59
22	Gayabari TG	3501.3	23.7	594.3	16.98	2907	83.02
23	Makaibari TG	3971.5	23.6	572.1	14.41	3399.4	85.59
24	Castleton TG	3999.6	23.8	570.1	14.25	3429.5	85.75
25	Spring Field TG	3776.5	27.0	581.2	15.39	3195.3	84.61
26	Bamanpokhri RO	3471	27	652.1	18.79	2818.9	81.21
27	Simulbari TG	2821.5	23.8	650.4	23.05	2171.1	76.95
28	Singeli TG	2479	18.9	580.3	23.41	1898.7	76.59
29	Thurbo TG	2131	18.6	457.2	21.46	1673.6	78.54
30	Okayti TG	2042.6		449.5	22.01	1593.1	77.99

MmP: Mean Monsoon Precipitation (June to October); MmT: Mean Temperature; MmE: Mean Monsoon Evaporation loss; TmR: Total Monsoon Run-off.

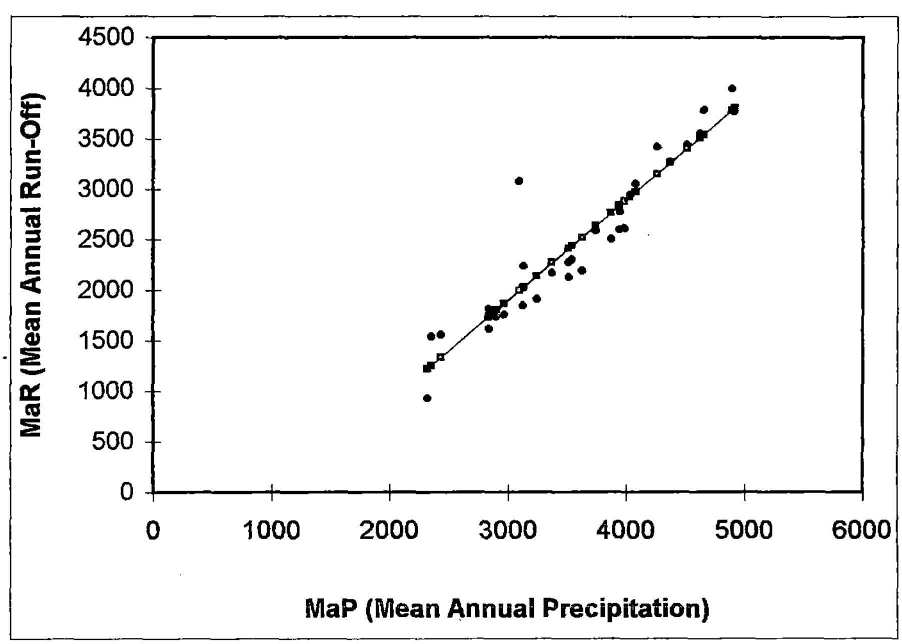
The winter season (November to February) receives an insignificant amount of precipitation, which cannot flow as run-off due to evaporation loss, transpiration and infiltration through the soil. Nevertheless, the major rivers of Kurseong Sub-Division like the Balason and the Mahananda record as much as 2.0 cumecs of discharge. The run-off slightly decreases to about 80 % along the northern tracts, 65-75 % along the central and 70 to 80 % along the southern margin of the study area during September. During October, the percentage of run-off to the total rainfall sharply decreases further 30 to 40 % in the study area.

6.3 RAINFALL – RUN-OFF CORRELATION

Run-off primarily depends on precipitation and is often found very closely related. Two linear regression analyses have been carried out to find out such relationship. The first case involves the relationship between mean annual precipitation and the mean annual run-off (Fig.6.1), while the second one involves the relationship between the mean precipitation during the monsoon months (June to October) and the respective run-off (Fig.6.2). The data has been obtained from 30 recording stations (Tables 6.1 & 6.2).

Figure 6.1

Relationship Between Mean Annual Precipitation and Run-Off



The correlation co-efficient between the mean annual precipitation (X) and the mean annual run-off (Y) is very high ($r = 0.937$) and have a 't' value of 14.155 which is significant at the level of 0.005 %. The regression equation is:

$$Y = -1080.432 + 0.994X \; (R^2 = 0.8774) \; \ldots\ldots.6.4$$

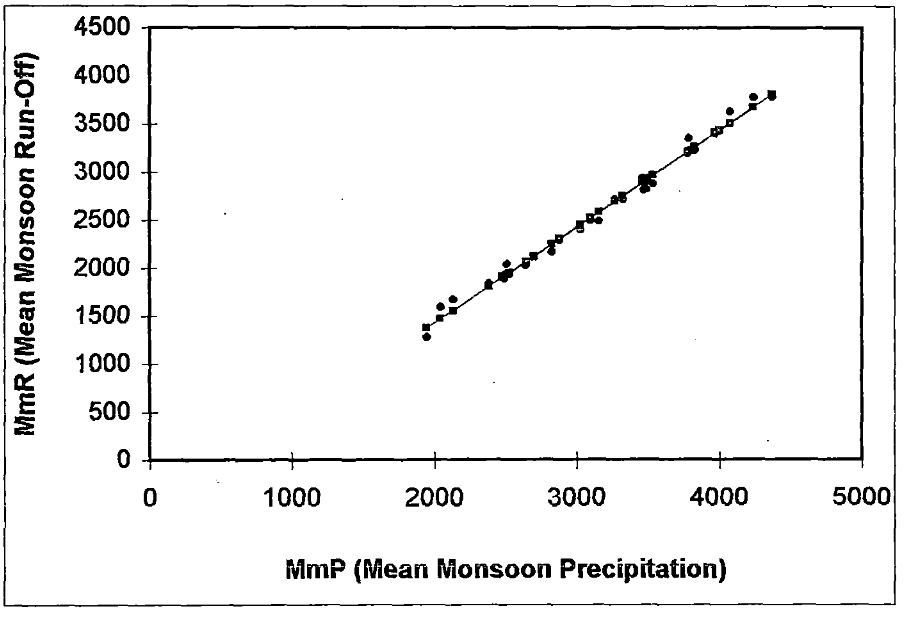
$$(SE = 259.23 \quad 0.07)$$

$$('t' = -4.17 \quad 14.16)$$

The slope of the regression line is of some value if a comparison is to be made between this relationship and that which exists in other areas. The co-efficient of determination ($R^2 = 0.8774$) shows that 87.74 % of the total variations in run-off may be explained by the respective precipitation, 16.26 % remain controlled by random factors.

Figure 6.2

Relationship Between Precipitation of Mean Monsoon Month and Run-Off



The relationship between the precipitation of monsoon months (X) and the respective run-off (Y) may be explained in the following equation:

$$Y = -580.064 + 1.004X \; (R^2 = 0.9895) \; \ldots\ldots 6.5$$

$$(SE = 63.22 \quad 0.02)$$

$$('t' = -9.18 \quad 51.35)$$

This is also a good prediction equation. The calculated 't' value indicates that the regression exercise is significant at the level of 0.005 %. The co-efficient of determination (R^2 = 0.9895) shows that 98.95 % of the total variations in Y has been explained by the respective independent variable.

The amount of run-off is thus, dependent on the amount of precipitation. The very high rate of run-off during the monsoon months is a positive indication of the non-existence of significant amount of forest cover, which may otherwise help in the retention of the sub soil water and thereby reduce the run-off.

6.4 STUDY OF EVAPORATION

The quantitative determination of the evaporation loss has been estimated based on Khosla's model (1950), where:

$$L_m = T_m{}^oC/0.2074 \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6.6$$

Where, L_m = monthly evaporation loss and $T_m{}^oC$ is the monthly average temperature in ^oC.
A detailed station-wise amount of evaporation loss has been tabulated (Table 6.1 & 6.2). It is found that the evaporation loss during monsoon months is about 10% along the northern part of the study area while, the loss has been estimated to be about 25% of the total precipitation along the southern margin of the study area. The mean annual evaporation loss has been estimated in between 20 to 30% in and around the north-eastern, central and the

western part of Kurseong Sub-Division of Darjeeling Himalaya. The mean annual evaporation loss has been estimated to be about 10% more than that of the monsoon months.

6.5 ESTIMATION OF WATER RESOURCES

The estimation of water resources of Kurseong Sub-Division has been carried out in two ways:

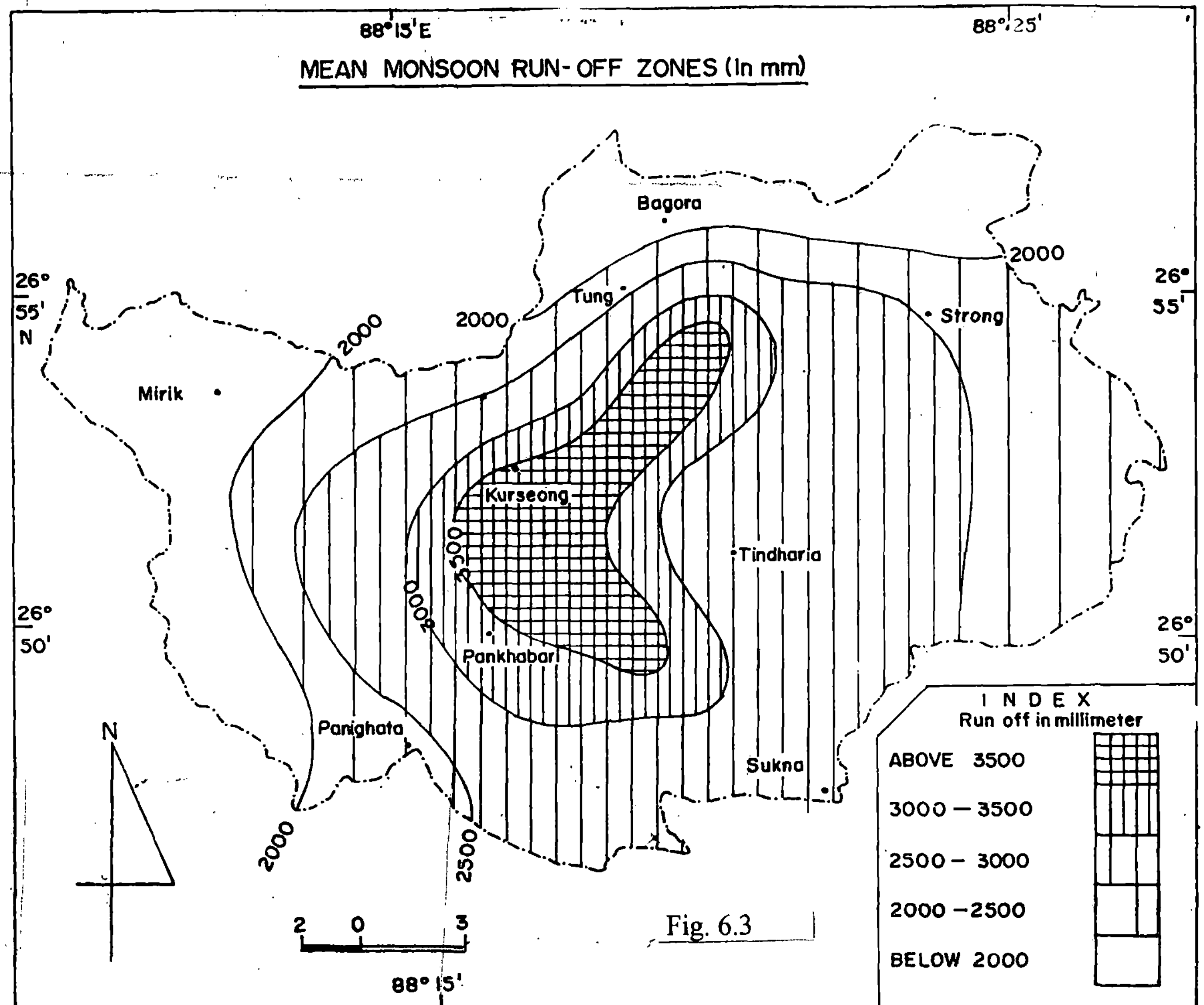
i) by the estimation of run-off empirically from long term average precipitation and temperature data (Khosla, 1950) and

ii) by the estimation of run-off from the daily discharge data of the major rivers like Mahananda, Balason, etc, over a considerable period.

The empirical estimation of run-off for the river has been determined in two ways, the first one is for the monsoon months and the other for the whole year. These two estimations will provide us with a better idea about the average available water resource in the study area. Although, the investigator has collected information on the actual run-off through the river, from the daily average discharge data but these seem to be inadequate for the planning of water conservation. This is due to the fact that the run-off and/or water resource depends on the actual precipitation and evaporation loss, which again vary much from year to year. Thus, the estimation of long-term average water resource based on empirical formula becomes necessary in the present case.

6.5.1 The Monsoon Water Resource

The monsoon run-off has been determined empirically for the different stations and shown in the Table 6.2. Based on the available total monsoon run-off, a run-off zone map for Kurseong Sub-Division has been prepared (Fig.6.3). Five major run-off classes have been identified and their respective area coverage along with total estimated run-off has been represented in the Table 6.3. Thus, the total water resource of the monsoon months for each class can be estimated easily by multiplying the respective area by its run-off and the



88°15'E
88°25'
MEAN MONSOON RUN-OFF ZONES (In mm)
26° 55' N
26° 55'
26° 50'
26° 50'
Bagora
Tung
Strong
Mirik
Kurseong
Tindharia
Pankhabari
Panighata
Sukna
2000
2000
2000
2000
2500
3000
3500
N
2 0 3
88° 15'
INDEX
Run off in millimeter
ABOVE 3500
3000 — 3500
2500 — 3000
2000 — 2500
BELOW 2000

Fig. 6.3

summing of all classes have produced the total monsoon surface water resource i.e. 1.067.146 million cubic meters.

Table 6.3

Monsoon (June – October) Water Resources of Kurseong Sub-Division

Sl. No.	Run-off Zones (in millimeters)	Area in Sq. km	Water Resources (in million cubic meter)
1	Above 3500	37.55	140.813
2	3000 – 3500	41.50	134.875
3	2500 – 3000	154.14	423.885
4	2000 – 2500	98.81	222.323
5	Below 2000	83.00	145.250
		Σ 415.00	Σ 1067.146

It is evident from the Figure 6.3 and Table 6.3 that the run-off zone of 3500 millimeter covers 9.05 % of total area but it contributes to 13.2 % of the total run-off. While, the class below 2000 millimeter covers an area of 20 % of area but contributes to only 13.61 % of the total run-off. It has been found that the moderate run-off of class 2000 – 2500 millimeter covers an area of 10.00 % which also contributes 12.63 % surface water resource of the study area. The run-off class 2500 to 3000 mm contributes to about 37.72 % (423.885 million cubic meters), which covers an area of 154.14 square kilometer or 37.14 % of the total study area. While, the run-off class below 2000 mm covers an area of 83.00 square kilometer or, 20 % of the total area which contributes only 145.25 million cubic meters or 13.61 % of the total surface run-off (Fig.6.3). The water resource of Kurseong Sub Division during the monsoon months as estimated by empirical method seems to be very much high (2.495 m^3/m^2). This is most probably due to a very high amount of rainfall on a deforested steep slope, which produces rapid run-off.

6.5.2 The Total Water Resource

In order to apprehend the nature and amount of the total annual water resource of the study area the investigator has tried to estimate the same from the map (Fig. 6.4) which has been prepared using data obtained from the Table 6.1 and Figure 6.3. The Table 6.4 shows the nature and amount of the total surface water resource of the study area.

Table 6.4

Total Water Resource of Kurseong Sub-Division

Sl. No.	Run-off Zones (in millimeters)	Area in Sq. km	Water Resources (in million cubic meter)
1	Above 3500	21.73	81.488
2	3000 – 3500	27.67	89.928
3	2500 – 3000	140.31	385.853
4	2000 – 2500	167.98	377.955
5	Below 2000	57.31	100.290
		Σ 415.00	Σ 1035.514

Out of the total annual surface water resource of the study area (1035.514 million cubic meter), the run-off class 2000 to 3000 mm contributes to the bulk share in both total water resource (73.76 %) and area (74.29 %). The very high total run-off area (>3500 mm) comprises only 5.24 % of the total area but contributes to 7.87 % of the total surface run-off. While, the very low run-off area (<2000 mm) contributes only 9.69 % of the total surface run-off (Fig. 6.4 and Table 6.4).

Thus, the total annual surface water of the study area has been estimated to be about 1035.514 million cubic meter which is 31.632 million cubic meter less than that of the monsoon months because, according to the present empirical formula, the non-monsoon rainfall have negative influence on the surface run-off.

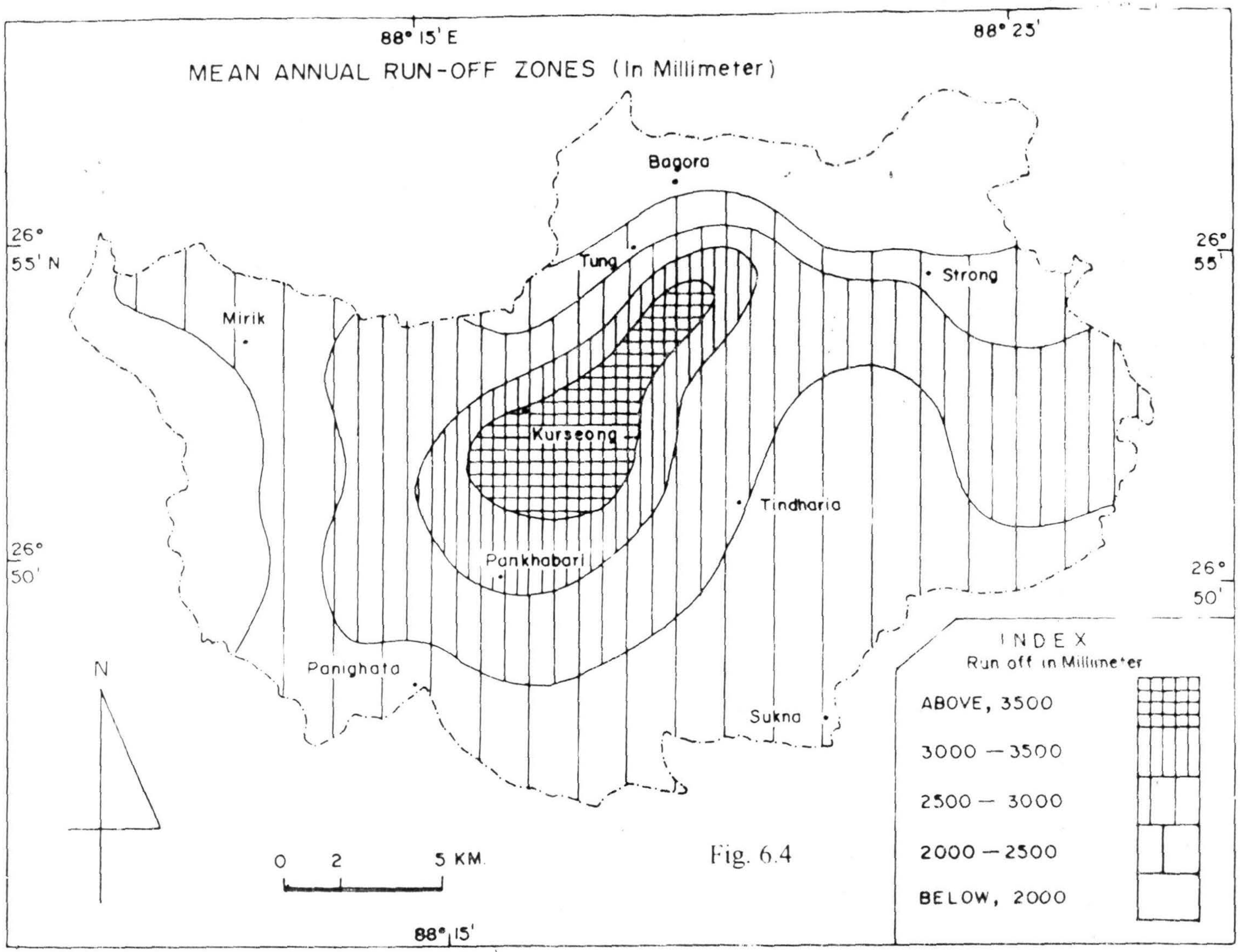

88° 15' E
88° 25'
MEAN ANNUAL RUN-OFF ZONES (In Millimeter)
Bagora
Tung
Strong
Mirik
Kurseong
Tindharia
Pankhabari
Panighata
Sukna
26° 55' N
26° 55'
26° 50'
26° 50'
N
0 2 5 KM.
88° 15'
INDEX
Run off in Millimeter
ABOVE, 3500
3000 — 3500
2500 — 3000
2000 — 2500
BELOW, 2000

Fig. 6.4

6.6 ESTIMATION OF SURFACE WATER RESOURCE BASED ON DISCHARGE DATA OF MAJOR RIVERS

It has already been mentioned that Kurseong Sub-Division of Darjeeling Himalaya is drained by the two major rivers, Balason and Mahananda of the Ganga System and portions of a few minor streams like Rayang of the Tista System (for details please refer to Chapter II). The investigator has tried to apprehend the discharge data of the Mahananda and Balason rivers from 1985 to 1996. This will ultimately help to estimate the actual surface water resource of the study area.

6.6.1 THE MAHANANDA CATCHMENT

The estimation of actual run-off of the rivers at Champasari has been carried out based on the daily average discharge data from the year 1985 – 1996. Average daily discharge in cumecs multiplied by 86400 gives the total run-off of the day in cubic meter (m^3), and the summation of 365 days will yield the total run-off of the year. The Mahananda basin covers 120.89sq. Km which accounts to about 29.13 % of the study area. It has been estimated that the total run-off of the river Mahananda at Champasari to be 692.654 million m^3 (average value of 11 years, 1985 – 1996). Out of this 627.481 million m^3 belongs to the monsoon months and the remaining 65.173 million m^3 estimated during the non-monsoon months (Table 6.5).

6.6.2 THE BALASON CATCHMENT

The Balason Catchment covers most of the west central part of the study area, which accounts about 39.89 % of the study area. The run-off of the river has been estimated at the gauging station at NH 31 near Matigara. The average run-off of the river has been estimated to be 1175.31 million m^3 (average of 11 years from 1985 – 1996) of which 87.23 % belongs to the monsoon months. The run-off data has been represented in the following Table 6.5

Table 6.5

Surface Water Resource of Selected Drainage Basins

Basin	Total Water Resource (in million m^3)		Monsoon Months (in million m^3)		Non-monsoon Months (in million m^3)	
	Total	Per km^2	Total	Per km^2	Total	Per km^2
Mahananda Basin	692.654	3.298	627.481	2.988	65.173	0.311
Balason Basin	1175.310	3.202	1025.207	2.793	150.103	0.409
Kurseong Sub-Division	1347.150	3.246	1191.62	2.871	150.95	0.364
Long Term Average Water Resources Based On Empirical Model						
30 to 40 years average	1035.514	2.495	1067.146	2.571	-31.632	-0.075
Average Of The Two Estimates						
	1191.33	2.871	1129.383	2.721	119.32	0.288

The Table 6.5 shows some interesting points relating to the empirical estimation and the actual surface water resource of the study area. It has been found that the long term average estimated water resource of Kurseong Sub-Division is less than that of the 11 years average of discharge through the major rivers. In case of the non-monsoon months according to the empirical estimation, there is negative value of –31.632 million m^3 while, the actual estimation based on the discharge data shows a positive value of 150.95 million m^3. However, the differences between these two estimations may be due to the following:

a) the actual estimation has been based on the daily average discharge of the rivers Mahananda and Balason;
b) while, in the empirical estimation the study has been based on long term average rainfall and temperature data of some selected stations and thereby, these are reliable in case of those sites only;
c) sub- terranian water flows as springs (locally known as jhoras) even in non-monsoon months account for the amount of 150.95 million m^3 of surface water, and
d) finally, the recharge of water through sewage disposal may also play an important role in the overall estimation of water resource.

6.7 CONCLUSION

The high intensity rainfall on steep degraded slopes of Kurseong Sub-Division of the Darjeeling Himalaya has caused high run-off and consequently, less water becomes available to saturate soil and recharge aquifers and thereby, induces phenomenal soil erosion and mass movements along the hill slopes. The case is just reverse in and around the foothills and lower Himalaya, where, moderately dense forest cover reduces the run-off and make some water available to form a good ground water reserve. From the point of quality, except high amount of iron at places, no serious problem of water pollution has been noticed by the investigator.

Out of the total surface water resource of 1035.514 million m^3 (based on long term empirical model) or 1347.15 million m^3 (based on discharge run-off model), nothing noteworthy has yet been utilised commercially. Similarly, its vast sub-surface water reserve remains commercially untapped. It is thus, imperative to find out suitable ways and means to conserve such huge unutilised water resource both surface and sub-surface. The construction of a number of check dams across the river at suitable sites to preserve the monsoonal supply for re-distribution during the non-monsoon months, would serve the immediate purpose adequately. Construction of mini-hydel projects, tapping the mountain torrents at suitable sites may also provide with the vital energy base for domestic and industrial activities in the Sub-Himalayan West Bengal. Such a comprehensive approach would require more than a theoretical interest in the protection of reservoir against situation and need serious involvement in the task of soil and water conservation measures in the catchment areas.

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