WATER TABLE AND ITS FLUCTUATIONS

INTRODUCTION

The saturated zone is obtained at the top by either a limiting surface of saturation or overlying impermeable strata, and extends down to underlying impermeable strata. In the absence of overlying impermeable strata, the upper surface of the zone of saturation is the "water table" or "phreatic surface" (Todd,1959). The water table separates the two zones sub-surface water in which the resulting forces and motions of sub-surface water are different. The interaction of molecular and colloidal forces with the gravitational forces gives rise to complex motions of sub-surface water above the water table and below it, the resulting movement or percolation of groundwater is mainly due to force of gravity which is generally not influenced by other forces except where the local heat is important. The water table outcrop delimits the surface areas subject to influent and effluent seepage. Influent seepage by streams takes place where the water table is below the stream beds. Effluent seepage starts at the intersection of the water table with ground surface. In an area, cut by stream erosion, the water table first outcrops where the stream changes from influent to effluent. The outcrop normally continues downstream near or at the margins of the low lands bordering the stream and may include large areas of bottom lands.

Topography is important in controlling the depth of the water table below the surface, as well as its shape. Under the ground surface, the water table is just a 'subdued replica' of the surface topography. Contour maps of the water table are graphic representations of the hydraulic slopes of the water table and are the basis for the studies of the direction and rate of motion of free water, recharge of groundwater from all sources and indicate changes in velocity of percolation or permeability of formations or both. The slope or profile of the water table is a graphic representation of the rate of percolation and permeability of water-bearing

LOCATION OF DUGWELLS UNDER STUDY

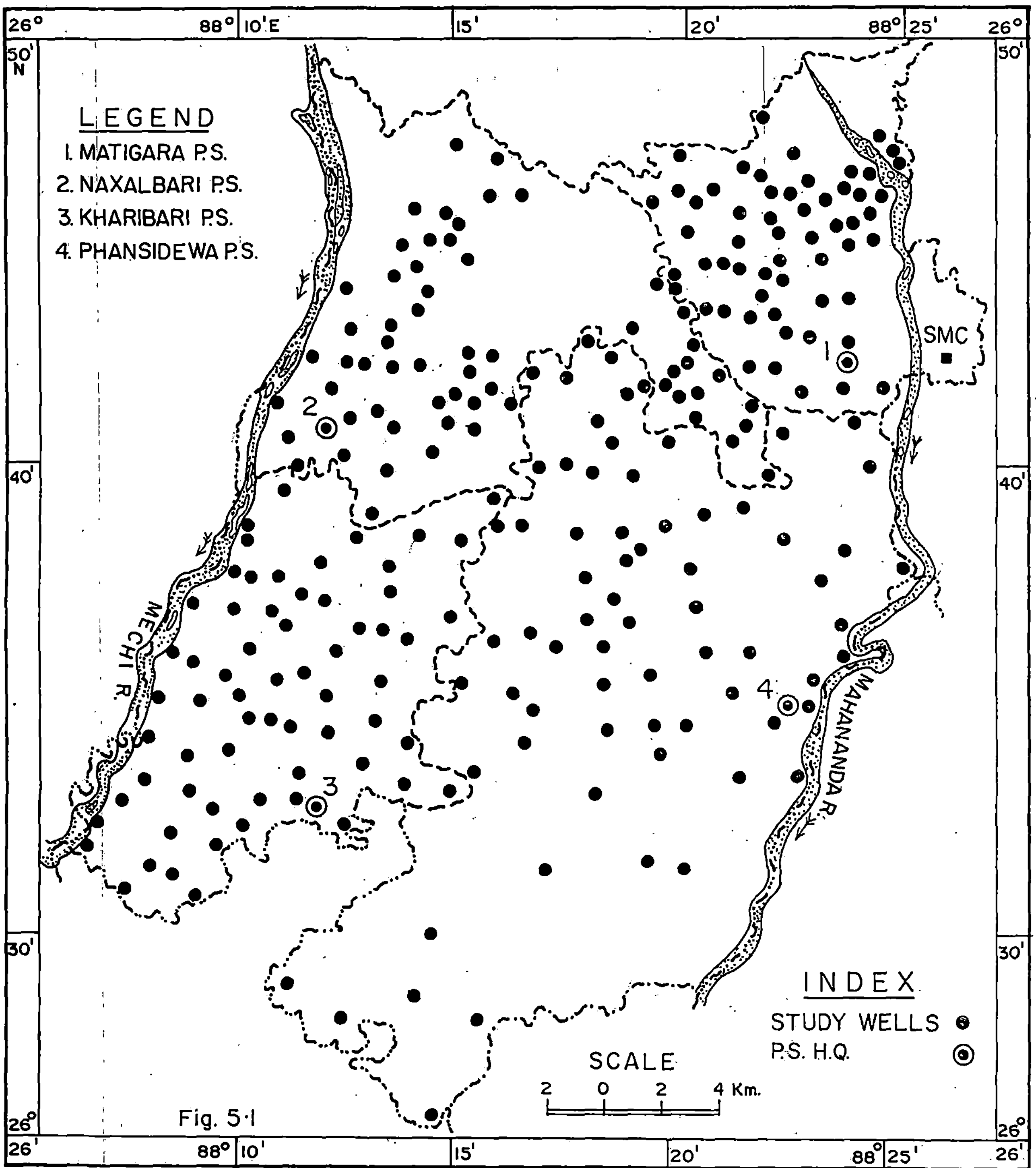


Fig. 5·1

materials. The fundamental law governing the interpretation of water table is that 'the slope varies directly as the velocity and inversely as the permeability'. Obviously if permeability is constant, the fastest motion of groundwater is towards the direction of maximum slope (Tolman, 1937). From the geological viewpoint, the water table separates the belt of weathering, oxidation, rock decomposition and solution from the underlying belt of mineral precipitation and rock cementation (Darcy, 1856).

5.1 LOCATIONS AND MEASUREMENTS OF STUDY WELLS

There are in all 251 study wells in the study area (Fig.-5.1). They are all open shallow masonary wells and are mostly situated along the roads and thus gives rise to different lines of wells. Each of the well is named after the block which it is situated. Study wells are more or less equally distributed all the block of the study area. A number of government organisations–SWID, CGWB, PHED etc. have measured a numbers of well's water level twice, thrice and four times respectively in a year. But the present researcher has measured the water level in each of the well twice a year, that is in April, preceding the break of monsoon rains, and again in November, following the end of the rainy season. The water table in the wells is measured by graduated steel tapes to the nearest thousandth of a meter from a predetermined measuring point marked on the concrete curb of a well. The water table depth data for the wells are available for the period 1997 to 1998 during the time of research work.

5.2 DEPTH TO WATER TABLE

The aerial variations in water table depths has been considered first of all. The factors controlling these variations would, obviously, be those which, at any place, do not themselves change so rapidly with time, for instance, climate, surface relief, geological structure and hydrogeological properties of the water bearing formation of the terai region. Water level measurements were taken in 251

AVERAGE DEPTH TO WATER TABLE (Pre-monsoon, 1998)

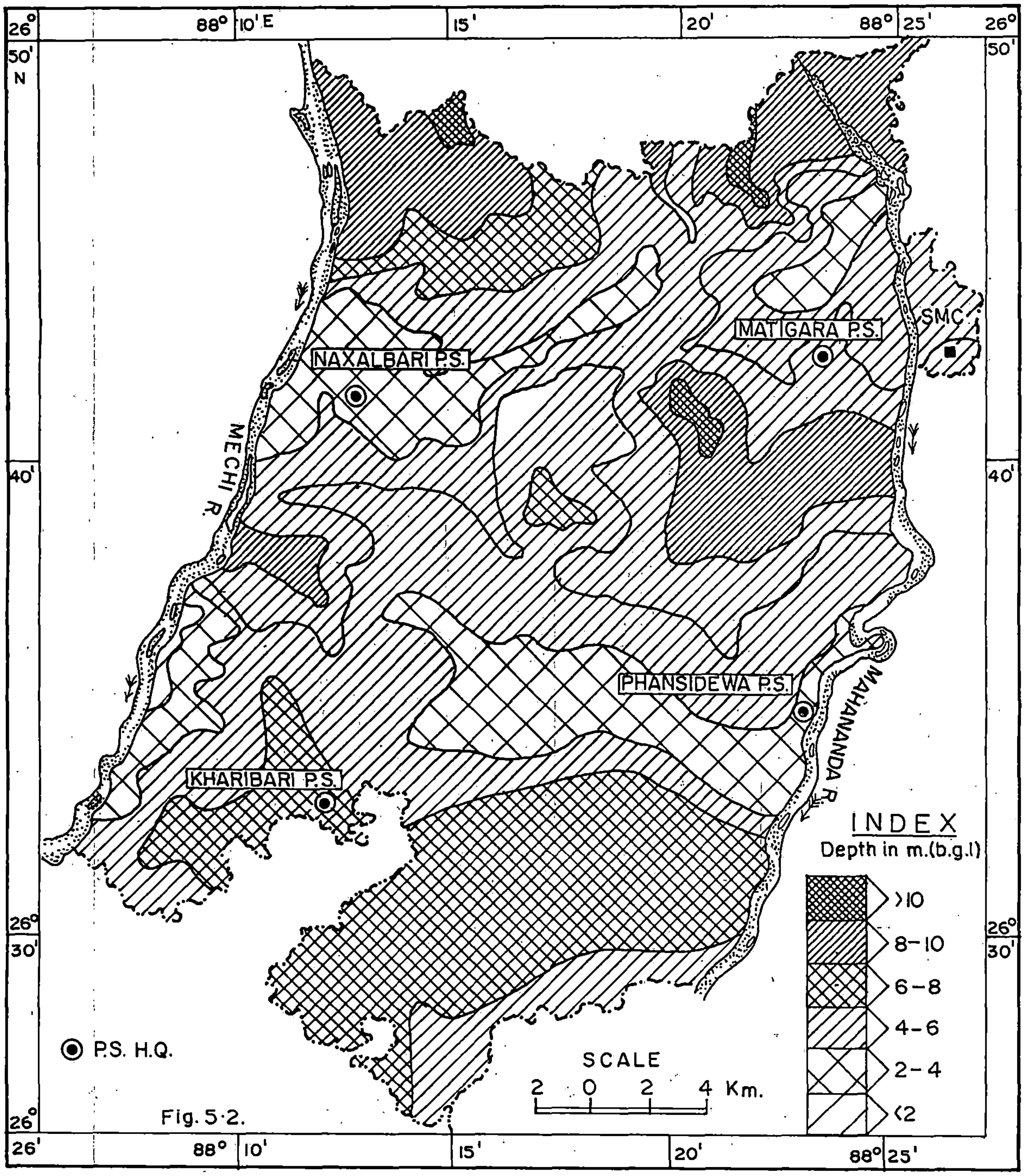
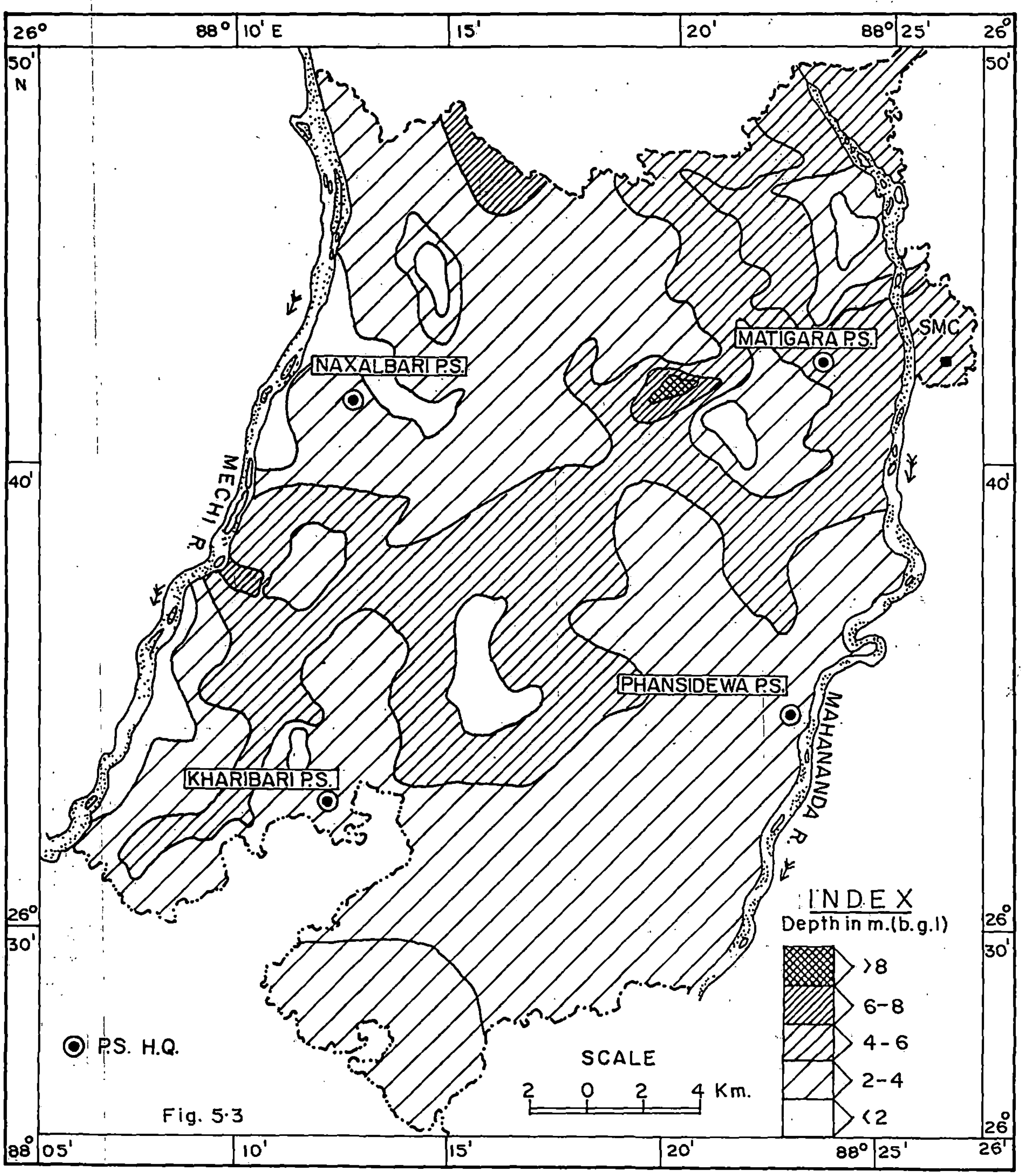


Fig. 5·2.

AVERAGE DEPTH TO WATER TABLE (Post-monsoon,1998)



WATER TABLE FLUCTUATION MAP IN 1998

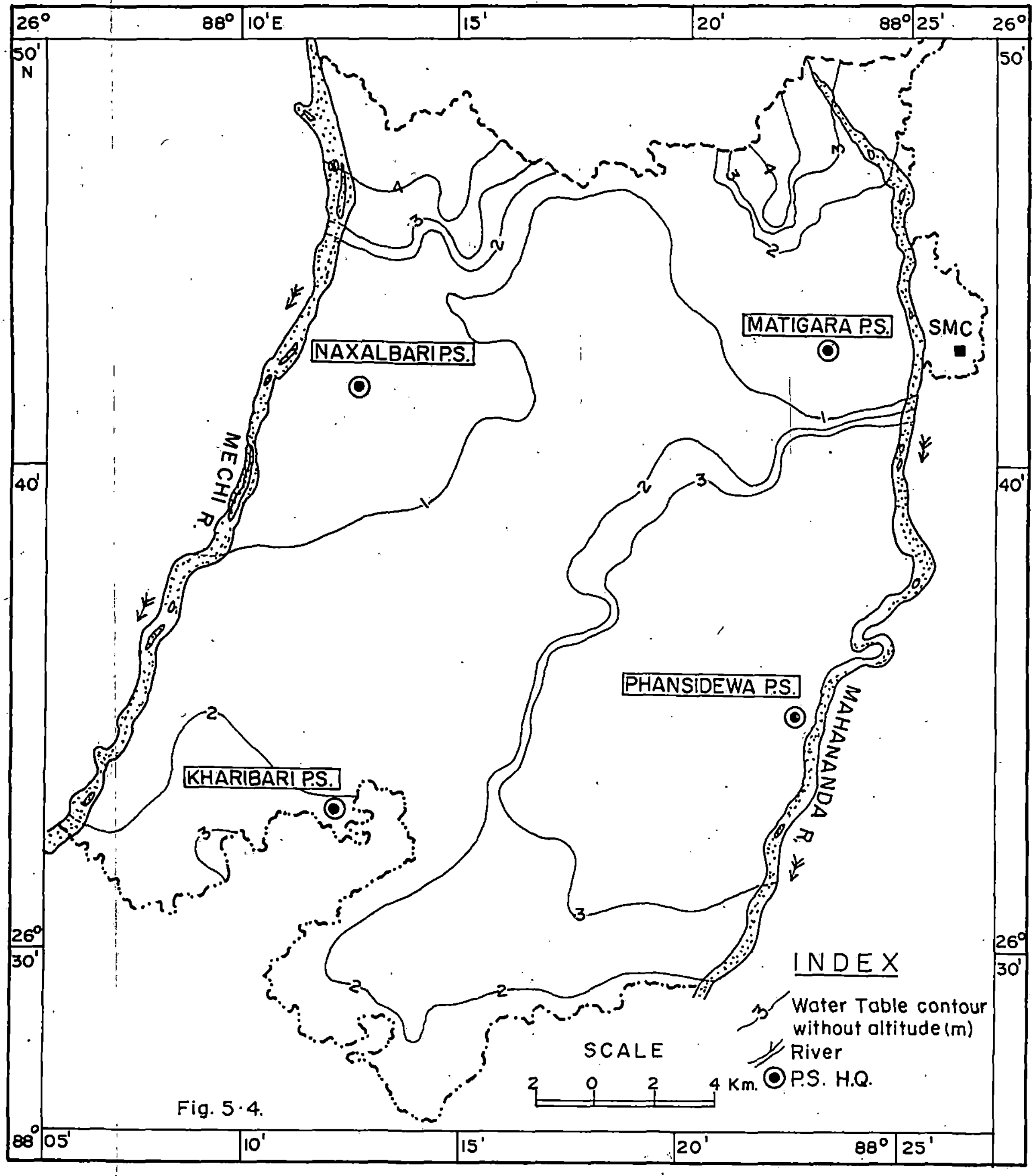


Fig. 5·4.

dugwells distributed all over the study area. The depth to the water table map prepared on the basis of hydrological data collected during the survey which shows water level conditions and its changes in different part of the study area (Figs.–5.2, 5.3 & 5.4). The range of the depth to water level in respect of 251 open dugwells is shown in Table – 5.1.

Table – 5.1 : Seasonwise range chart of average depth to waterlevel in open dugwells

Depth to water level in m b.g.l	No. of measured well in range		Total percentage		Cumulative percentage	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
0.01-1.00	00	01	0.00	0.40	0.00	0.40
1.01-2.00	01	13	0.40	5.18	0.40	5.58
2.01-3.00	07	70	2.79	27.89	3.19	33.47
3.01-4.00	44	91	17.53	36.25	20.72	69.72
4.01-5.00	73	38	29.08	15.14	49.80	84.86
5.01-6.00	62	25	24.70	9.96	74.50	94.82
6.01-7.00	23	08	9.16	3.19	83.66	98.01
7.01-8.00	13	04	5.18	1.59	88.84	99.60
8.01-9.00	17	01	6.78	0.40	95.62	100.00
9.01-10.00	05	00	1.99	0.00	97.61	100.00
10.01-11.00	05	00	1.99	0.00	99.60	100.00
11.01-12.00	01	00	0.40	0.00	100.00	100.00

Analysing the Table–5.1, it is found that the depth of water in pre-monsoon covering 88% of wells lies within 8 m b.g.l indicating depth to water in general ranges between 2 m and 8 m b.g.l Whereas in the same depth is covering 99% of wells during the post-monsoon period and indicating depth to water in general ranges between 0 m and 8 m b.g.l Moreover, only 53.78% of wells of the total lies within 4 m to 6 m b.g.l during pre-monsoon period but during the post-monsoon period, only 64.14% of wells of the total lies within 2 m to 4 m b.g.l The deepest water level in pre-monsoon 11.5 m b.g.l was recorded in the well (M_{26}) located at Sukna Environmental Research Station of Matigara P.S. and the shallowest level in the same season is 1.42 m b.g.l was recorded in the well (K_{12})

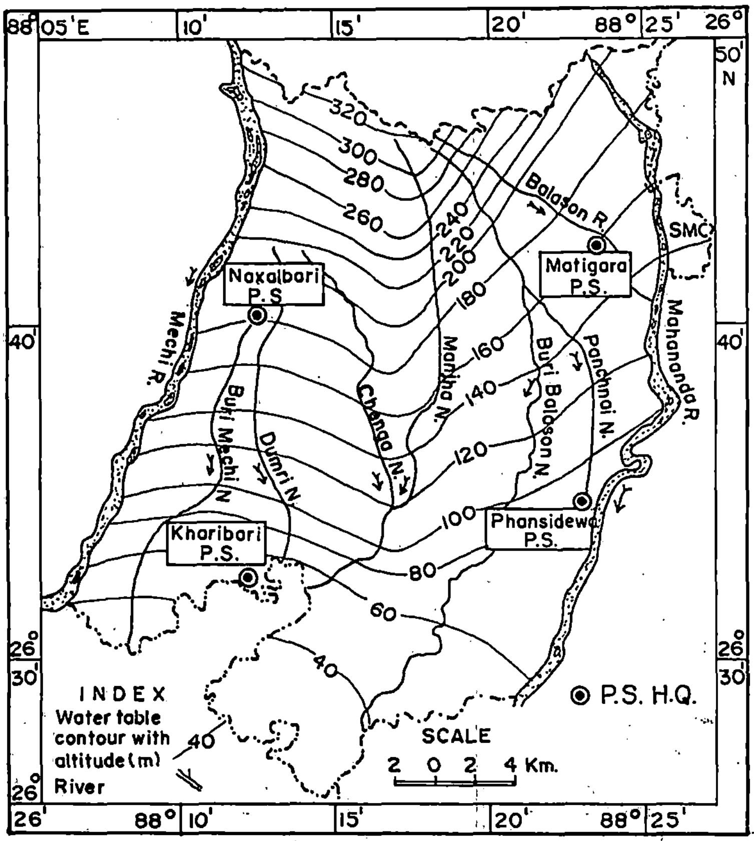


Fig.- 5·5: WATER TABLE CONTOUR MAP
(Pre-monsoon, 1998)

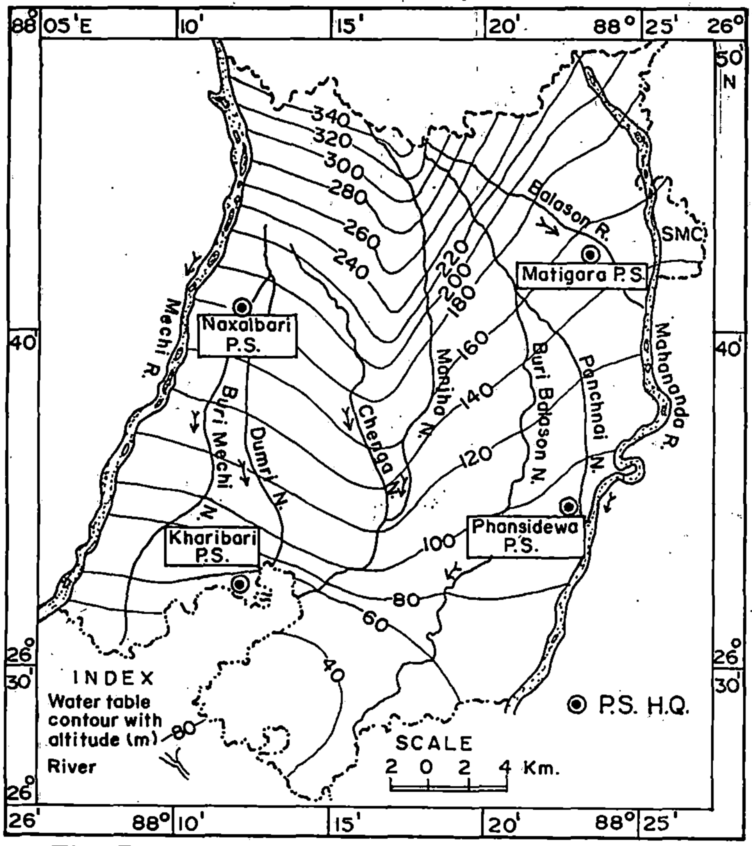


Fig.- 5·6: WATER TABLE CONTOUR MAP
(Post-monsoon, 1998)

located at Chunilal village of Kharibari P.S. On the other hand, the deepest water level in post-monsoon season 8.39 m b.g.l was recorded in the well (K_{05}) located at Antaram village of Kharibari P.S. and the shallowest level in the same season is 0.98 m b.g.l was recorded in the well (N_{11}) located at Mirjangaler Chhat of Naxalbari P.S. The diameter of the wells ranges from 0.61 m to 2.44 m and the depth of the wells varies between 1.95 m and 13 m. It is observed that the depth of water in general is found to be high (>8 m) in the vicinity of the hilly tract. The groundwater table's depth ranges from 0 m to 4 m at eastern, western and the extreme southern portion in the vicinity of the three rivers–Mahananda, Mechi and Balason respectively. But the deeper water levels ranges from 4m to 8m at the middle of the study area and located on both the sides of the bank of river Balason. The water level in general varies from place to place i.e., increasing towards the hilly tract and decreasing towards the streams and rivers. These features have been brought out even more clearly by the comparison of the surface contour map (Fig.–3.8) and water table contour map (Figs.–5.5 & 5.6). However, the effects of the other three factors, that is, climate, geological structure and hydrogeological properties of the water bearing formations, are hardly noticeable as they themselves exhibit but little aerial variations.

5.3 FORMS AND GRADIENT OF WATER TABLE

The water table is nearly a level surface. In fact, it exhibits distinct relief features. As has already been ascribed, the aerial variations in the depth of the water table reflect the form of surface relief. Thus, the water table is a subdued replica of the ground surface. To study the behaviour and movement of the groundwater in the area, a water table contour map has been prepared (Figs.–5.5 & 5.6) with reference to mean sea level as datum taking into consideration of the depth of water level data measured during May, 1998 and November, 1998, for determining the elevation of measuring points, the leveling work was carried out and all these measuring points were connected with the Survey of India benchmark available in the area.

Water table contour map reflects the effect, on the water table, of geological, topographical and hydrologic properties of the water-bearing formations of a region and represents graphically the equilibrium relations between velocity, hydrologic properties of water-bearing materials and water table slopes of free groundwater. The water table depth of 251 open dugwells, situated in the study area, have been incorporated for the present study. Contour maps of water table or the piezometric surfaces together with the flow lines, are useful data for locating the new wells.

The phreatic surface generally follows the topography of an area. The groundwater movement and direction which is normal to the contour and corresponding water table contour maps of pre-monsoon and post-monsoon of 1998 reveal that groundwater flows south-easterly in Siliguri-Sukna tract while in Trihana-Ambari tract it is in southerly direction. It is also analyzed that the water table contours are flexed towards down streams which clearly reveal the fact that all the streams and rivers flowing in the study area are effluent in nature. For stream losing (influent) water, the contour lines bend down stream and for streams gaining (effluent) water they bend upstream

Hydraulic gradient is expressed as the change in the head per unit distance and is denoted by dh/dt. A water table contour map or a contour map of the potentiometric surface of a semi-confined aquifer is a graphic representation of the hydraulic gradient of water table or potentiometric surface. The hydraulic gradients, which can be directly derived from the contour maps, are the basis for calculating the rate of groundwater flow through cross sections of the study area boundaries. The hydraulic gradient is maximum in the direction of the flow line. The gradients are generally comparatively high in groundwater recharge areas, close to influent streams over deep water tables, along the banks of deeply incised effluent streams and in heavily pumped areas. The gradients are low in groundwater discharge areas, valley bottoms and extensive plains. On steeper slopes the potential gradient and velocity of groundwater are relatively high and the flow path is comparatively shorter than under uplands and valleys. In relation to land surface slope, hydraulic gradients in recharge areas are generally steeper than those in discharge areas. Hydraulic gradient in the area of investigations varies widely due to its undulating nature. A steeper hydraulic gradient of 4 m per km is observed in Naxalbari-Kharibari section whereas it is about 1 m per km in Sevok-Siliguri tract. In Trihana-Bagdogra tract the steepest hydraulic gradient of 10 m per km is observed. However, interfluve area of the Mahananda-Manjha has a more flat hydraulic gradient of less than a meter per km and groundwater flow is towards south to south-west (Saha, 1998).

5.4 FLUCTUATION OF WATER TABLE

The water table stage fluctuates almost continually under the combined influence of a set of forces--causing recharge to or discharges from the groundwater reservoirs. Thus, a water table rise is registered when groundwater recharge exceeds discharge, whereas a decline occurs when discharge exceeds recharge. The rate of magnitude of water table fluctuations in any period, obviously depend upon the net effect of the recharge and discharge during that period. The water table also fluctuations. It is higher in the rainy season and lower in dry and hot weather. The water table that fluctuates from time to time is called the temporary water table. But there is a limit below which it never falls and this is known as permanent water table. It is commonly observed that recharge results from factors like influent seepage from rainfall and surface water bodies, groundwater inflow etc., whereas discharge occurs due to evaporation and transpiration, effluent seepage into streams, groundwater outflow, pumping from wells and so on. Only three factors—rainfall, pumping by wells and effluent seepage into streams and rivers have been found influencing the fluctuation of water table in the area under investigation. As compared to the tubewells, the rate of withdrawl from the open dugwell is, however, too low to significantly affect the water tables. The influence of groundwater inflow or outflow is also not

Fig.-5·7(a): HYDROGRAPH OF SELECTED NETWORK STATIONS

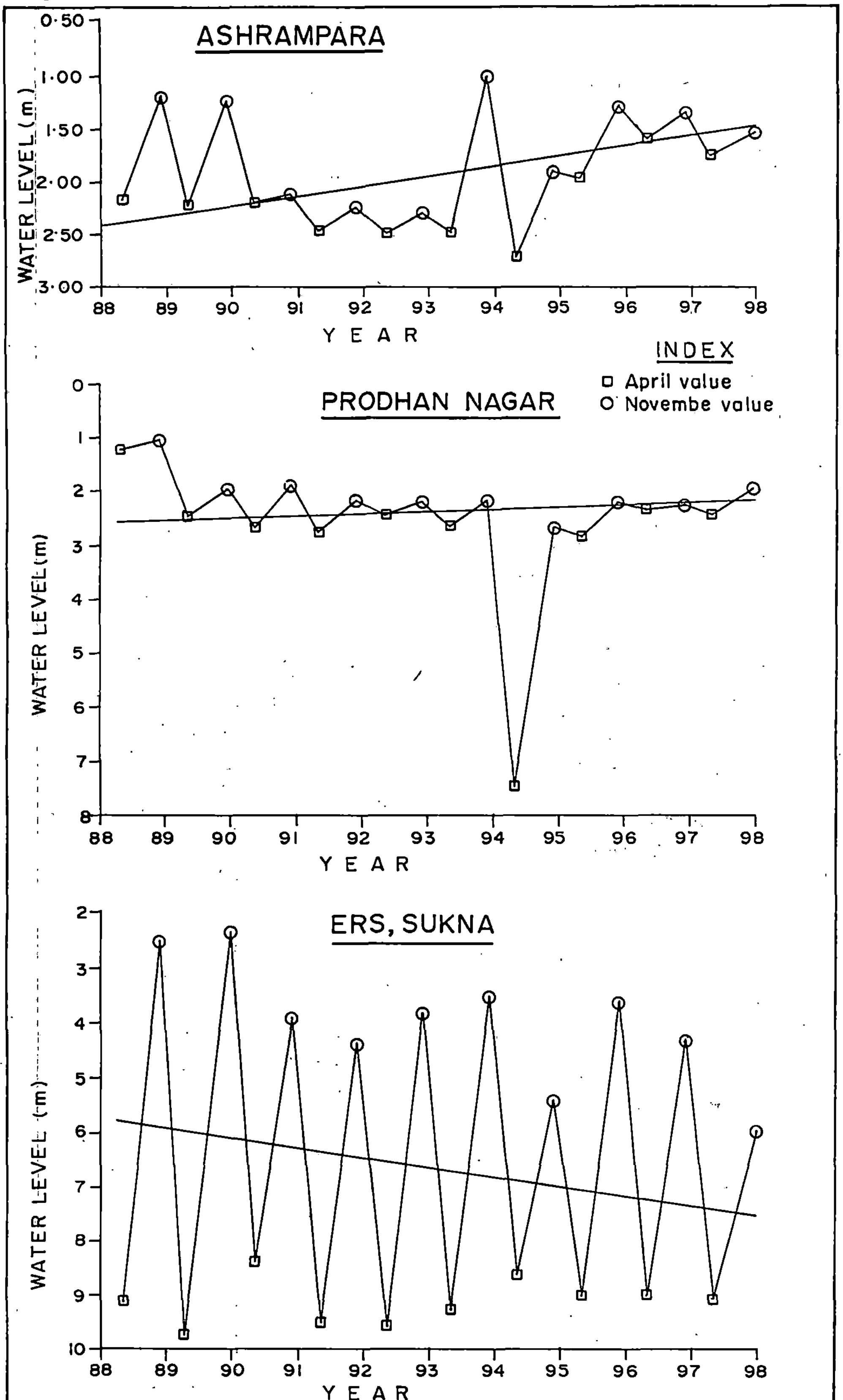
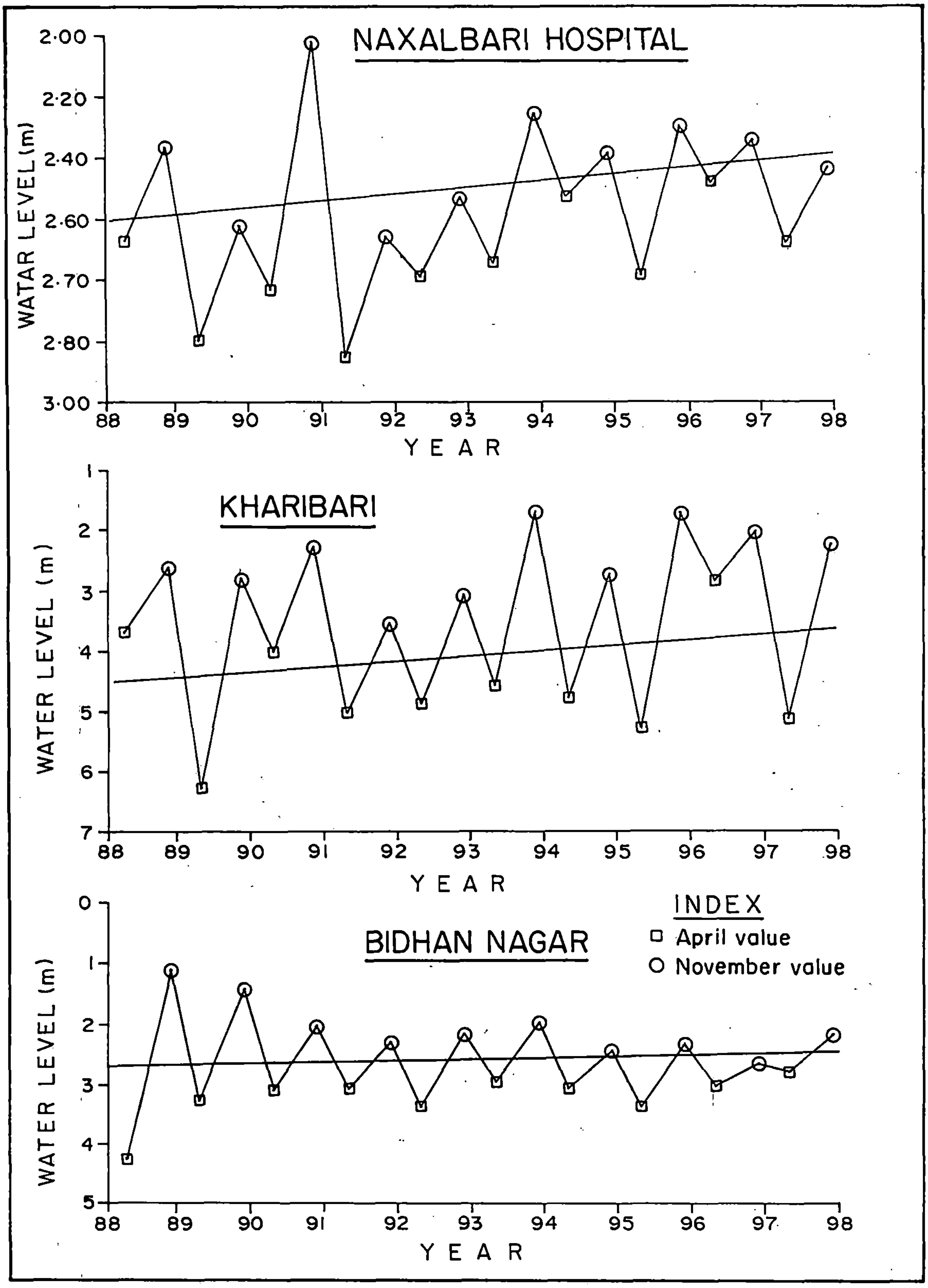


Fig.-5·7(b): HYDROGRAPH OF SELECTED NETWORK STATIONS



significant since, for all practical purposes, the one is approximately equal to the other.

Table – 5.2 : Average water level changes for all of the study wells (1977 – 1998)

Year	Water table changes in mm		
	April to November	November to April	Annual
1977 – 78 A low rainfall year (R.F. = 2143mm)	+ 0.86	- 0.65	+ 0.21
	+0.95	- 1.00	- 0.05
1980 – 81 A normal rainfall year (R.F. = 3337mm)	+4.50	-4.50	0.00
	+4.35	-4.35	0.00
1982 – 83 A heavy rainfall year (R.F. = 6096mm)	+6.25	-4.50	+1.75
	+6.15	-4.50	+1.65

As pointed out earlier, groundwater in the study area is, normally available at least upto a depth of about 6 to 8 meters, ordinarily reached by the open dug wells, as well as upto100 to 120 meters reached by the tube wells in the area underlying the piedmont and also the alluvial plains. Hence, the groundwater level fluctuation, noted from the observation wells, represent the fluctuations of the water table. The average water level data of 251 study wells (Table–5.2) and the hydrographs of six selected network monitoring stations (Fig.–5.7) give a fairly clear picture of the water-table fluctuations over the area. Amongst them five show positive relationship, which mean fluctuation is low due to high recharge for higher infiltration of rainfall.

A study of the water balance, involving water surplus and deficiency estimations, becomes highly significant in the present case, because local monsoon rainfall is the source of groundwater recharge. This study provides a full picture of the disposal of rainfall and irrigation water by the different processes for instance, evapo-transpiration, soil-moisture replenishment, effluent seepage into rivers and surface runoff effective in the area. The portion of rainfall and

Table-5.3 : Water balance in the areas outside of canal and tubewell irrigation (1977 to 1998). [Upper Figure : a low rainfall year (1977-78), Middle Figure : a normal rainfall year (1980-81) and Lower Figure : a heavy rainfall year (1982-83)].

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Potential evapotranspiration	72.50	110.50	140.35	166.70	195.25	150.05	135.35	105.45	112.25	120.01	115.65	78.15	1479.2
	2.80	4.90	10.50	19.20	317.50	343.50	518.30	574.50	327.70	21.30	2.40	0.00	2143.0
Rainfall	25.70	3.70	27.70	58.30	292.60	524.90	1226.7	699.60	470.30	6.30	0.00	1.00	3337.0
	0.00	0.00	51.30	148.20	289.20	720.90	1568.8	2957.4	242.60	68.70	48.40	0.00	6096.0
	0.00	0.00	0.00	0.00	0.00	0.00	125.00	0.00	-42.00	-83.00	0.00	0.00	-
Changes in soil moisture storage	0.00	0.00	0.00	0.00	0.00	0.00	125.00	0.00	-63.00	-62.00	0.00	0.00	-
	0.00	0.00	0.00	0.00	0.00	0.00	125.00	-25.00	-21.00	-79.00	0.00	0.00	-
	0.00	0.00	0.00	0.00	0.00	0.00	125.00	125.00	83.00	0.00	0.00	0.00	-
Soil moisture storage	0.00	0.00	0.00	0.00	0.00	0.00	125.00	125.00	62.00	0.00	0.00	0.00	-
	0.00	0.00	0.00	0.00	0.00	0.00	125.00	100.00	104.00	0.00	0.00	0.00	-
	2.80	4.90	10.50	19.20	317.50	343.50	135.35	105.45	112.25	115.60	2.40	0.00	1169.4
Actual evapo-transpiration	25.70	3.70	27.70	58.30	292.60	524.90	135.35	105.45	112.25	60.00	0.00	1.00	1346.9
	0.00	0.00	51.30	148.20	289.20	720.90	135.35	105.45	112.25	105.45	48.40	0.00	1716.5
	69.70	105.60	129.85	147.50	.0.00	0.00	0.00	0.00	0.00	98.71	113.25	78.15	742.7
Water deficiency	46.80	106.80	112.65	108.40	0.00	0.00	0.00	0.00	0.00	113.71	115.65	77.15	681.2
	72.50	110.50	89.05	18.50	0.00	0.00	0.00	0.00	0.00	51.31	67.25	78.15	487.3
	0.00	0.00	0.00	0.00	122.25	193.45	382.95	469.05	215.45	0.00	0.00	0.00	1383.2
Water surplus	0.00	0.00	0.00	0.00	97.35	374.85	1091.4	594.15	358.05	0.00	0.00	0.00	25.15.8
	0.00	0.00	0.00	0.00	93.95	570.85	1433.5	2851.9	130.35	0.00	0.00	0.00	5080.6
	0.00	0.00	0.00	0.00	0.00	0.00	20.00	25.05	10.15	0.00	0.00	0.00	55.2
Run-off	0.00	0.00	0.00	0.00	0.00	50.00	205.00	38.10	15.12	0.00	0.00	0.00	308.2
	0.00	0.00	0.00	0.00	0.00	105.00	265.35	301.05	10.30	0.00	0.00	0.00	681.7
	0.00	0.00	0.00	0.00	122.25	193.45	362.95	444.00	205.30	0.00	0.00	0.00	513279
Groundwater recharge	0.00	0.00	0.00	0.00	97.35	324.85	886.35	556.05	342.93	0.00	0.00	0.00	2207.5
	0.00	0.00	0.00	0.00	93.95	465.85	1168.1	2550.9	120.05	0.00	0.00	0.00	4398.9

WATER BALANCE IN THE STUDY AREA

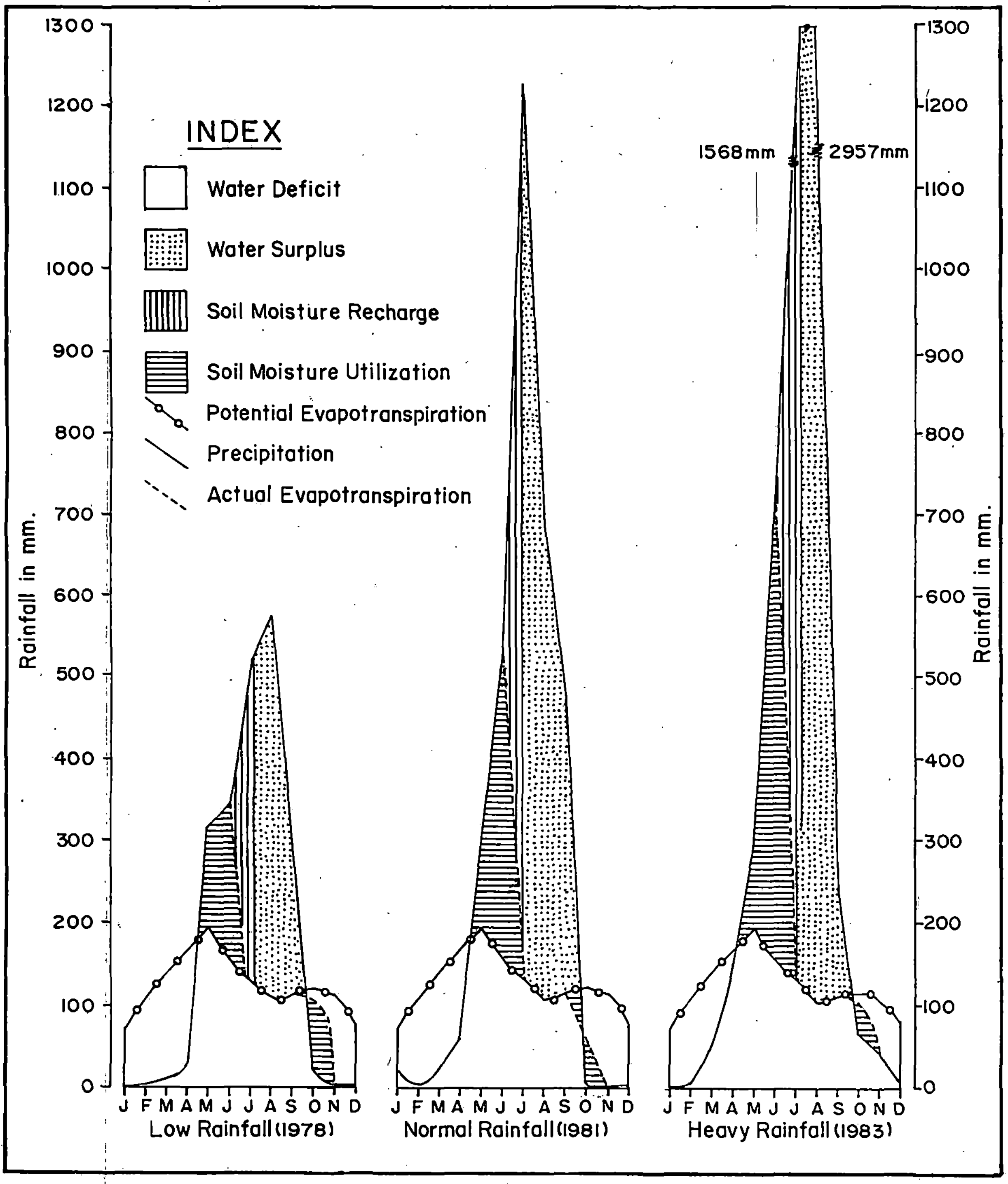


Fig. 5·8

irrigation water reaching the water table, depend upon the rate of its disposal by these processes.

The water balance for a heavy, a low and normal rainfall year, are set out for the areas–(i) the areas outside canal and tubewell as well as dugwell irrigation and (ii) the areas under canal, tubewells, dugwells and Jhora irrigation (Tables–5.3 and 5.4). The salient features of these tables are graphically presented in Fig.–5.8. Tanks and ponds have been used to measure evapo-transpiration losses, standard soil sampling tubes for soil moisture, and Parshall flumes with recorders for surface runoff measurements. Besides the Irrigation Department, terai Meteorological sub-station at Gangaram Tea Estate and Central Water Commission, Siliguri were consulted. It becomes obvious from the comparison of Tables 5.3 and 5.4 that they do not exhibit any significant differences as regards water surplus and deficiency since the influence of the controlling factors remains almost uniformly similar all over the area. However significant differences as regards potential and actual evapo-transpiration losses are to be noted between the two on account of the prevalence of irrigation in one of them (Table–5.4), its effect being to increase the losses.

Due to incomplete and in the absence of a continuous long term water table depth data in the monthly interval, the water table depth data of open dugwell are only available for the months of April and November in a year, done by the CGWB from 1985 to till now. Hence, the critical examination and accurate analysis of the fluctuations of water table in terai area are not possible. However, the factors, which are of utmost importance in affecting the water table fluctuations, are studied and the results derived therefrom are described.

a) Related to Rainfall :

The water table fluctuations in any year in the area of investigations are wholly controlled by the variations in local rainfall amounts. Due to the hilly physiography and steep gradient, most of the rivers and streams in the areas are

Table-5.4 : Water balance in the areas under canal, tubewells, dugwells and jhoras irrigation (1977-1998). [Upper Figure : a low rainfall year (1977-78), Middle Figure : a normal rainfall year (1980-81) and Lower Figure : a heavy rainfall year (1982-83)].

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Potential evapotranspiration	97.90	135.90	165.75	192.10	220.65	175.45	160.75	130.85	137.65	145.41	141.05	103.55	1807.0
Rainfall plus irrigation	15.50	17.60	23.20	31.90	342.90	368.90	531.00	587.20	358.18	51.78	15.10	12.70	2355.9
	38.40	16.40	4040	71.00	318.00	550.30	1239.4	712.30	500.78	36.78	12.70	13.70	3550.2
	12.70	12.50	64.00	160.90	314.60	746.30	1581.5	2970.1	273.08	99.18	61.10	12.70	6245.7
Changes in soil moisture storage	0.00	0.00	0.00	0.00	0.00	0.00	125.00	0.00	-30.00	-95.00	0.00	0.00	-
	0.00	0.00	0.00	0.00	0.00	0.00	125.00	0.00	-50.00	-75.00	0.00	0.00	-
	0.00	0.00	0.00	0.00	0.00	0.00	125.00	-25.00	-15.00	-85.00	0.00	0.00	-
Soil moisture storage	0.00	0.00	0.00	0.00	0.00	0.00	125.00	125.00	95.00	0.00	0.00	0.00	-
	0.00	0.00	0.00	0.00	0.00	0.00	125.00	125.00	75.00	0.00	0.00	0.00	-
	0.00	0.00	0.00	0.00	0.00	0.00	125.00	125.00	125.00	0.00	0.00	0.00	-
Actual evapo-transpiration	15.50	17.60	23.20	31.90	342.90	368.90	160.75	130.85	137.65	175.35	15.10	12.70	1432.4
	38.40	16.40	40.40	71.00	318.00	550.30	160.75	130.85	137.65	108.69	12.70	13.70	1598.8
	12.70	12.50	64.00	160.90	314.60	746.30	160.75	130.85	137.65	150.08	61.10	12.70	1964.1
Water deficiency	82.40	118.30	142.55	160.20	0.00	0.00	0.00	0.00	0.00	93.63	125.95	90.85	813.9
	59.50	119.50	125.35	121.10	0.00	0.00	0.00	0.00	0.00	108.63	128.35	89.85	752.3
	85.20	123.40	110.75	31.20	0.00	0.00	0.00	0.00	0.00	46.23	79.95	90.85	558.6
Water surplus	0.00	0.00	0.00	0.00	122.25	193.45	370.25	456.35	220.53	0.00	0.00	0.00	1362.9
	0.00	0.00	0.00	0.00	97.35	374.85	1078.7	581.45	363.13	0.00	0.00	0.00	2495.4
	0.00	0.00	0.00	0.00	93.95	570.85	1420.8	2839.3	135.43	0.00	0.00	0.00	5060.2
Run-off	0.00	0.00	0.00	0.00	0.00	0.00	15.50	18.35	10.35	0.00	0.00	0.00	44.2
	0.00	0.00	0.00	0.00	0.00	0.00	46.35	40.15	16.20	0.00	0.00	0.00	102.7
	0.00	0.00	0.00	0.00	0.00	0.00	270.55	345.25	17.78	0.00	0.00	0.00	633.5
Groundwater recharge	0.00	0.00	0.00	0.00	122.25	193.45	354.75	438.00	210.18	0.00	0.00	0.00	1318.6
	0.00	0.00	0.00	0.00	97.35	374.85	1032.3	541.30	346.93	0.00	0.00	0.00	2392.7
	0.00	0.00	0.00	0.00	93.95	570.85	1150.2	2494.0	117.65	0.00	0.00	0.00	4426.7

effluent in nature which leads to the conclusion that these effluent seepage are not significant at all to cause any groundwater storage or recharge. Even, the fluctuations over the two areas do not exhibit any marked aerial variations since factors like climate, geology, relief, soil, vegetation and hydrologic properties of the underlying rock formations reveal a general uniformity all over the study area. Moreover, the water table changes in any area in the two areas are identical (Table –5.2). A 'low', 'normal' and a 'heavy' rainfall year may be taken to correspond with June to September rainfall amounts of less than 2500 mm, 4500mm, to 6000mm, and more than 6000mm respectively by considering the Terai Meteorological sub- station at Gangaram T.E. of Phansidewa P.S.

Generally the water table in the piedmont plains is deeper than that of alluvial plains and average level ranges between 4m and 6m b.g.l during the post monsoon period and it varies from 8m to 10m b.g.l during the pre monsoon period. Seasonal fluctuations of water table is also higher in this zone ranging between 4m to over 6m In the alluvial plains the water table generally varies from 2m to 6m below ground level during pre monsoon period and 0.75m to 4.5m b.g.l during the post monsoon period. The seasonal fluctuations of water table in the alluvial plain is restricted within 2.5m only. In marginal areas between piedmont and the alluvial plains, behaviour of water level shows a general disposition with very low fluctuations between pre and post monsoon seasons (Figs.– 5.2 & 5.3).

Repeat water level measurements along with values of fluctuations from 251 study wells were taken during the month of April, 1998 for determination of change of water level in these wells during the period from November 1998 to January, 1999. In general, it shows a reversion in water level maximum of 6.25m which was recorded in the well (N_{37}) located at Dakshin Bagdogra of Naxalbari block. Some of the wells recorded a rise in water level, the maximum 5.61m at Siliguri P.S. and the maximum rise of water level is 0.53m in the well (K_{47}) located at Manjaya village of Kharibari P.S. Depending upon the regional fluctuations records in water level, a map of water level fluctuations has been prepared (Fig.-5.4) for the terai area of Darjiling district.

The water levels are being monitored with the help of 6 hydrograph stations covering SMC, Matigara, Naxalbari, Kharibari and Phansidewa block is being carried out 4 to 5 times a year by CGWB, Calcutta. Statistical analysis of the available water level data of those hydrograph stations for the last 10 years has been done to know the behaviour of the groundwater levels in time and space as shown (Appendix–III). By comparing the CGWB's long term discontinuous hydrograph data with those of water levels taken during the last 2 years i.e. 1997 and 1998. Based on these water levels data, 6 hydrographs of depth to water levels were down to depict the fluctuations in water levels (Fig.–5.7). The fluctuations are due to net withdrawl of water from or addition to the groundwater reservoirs. From the analysis of 6 hydrographs network observation wells and by comparison of water levels of April 1997 and April 1998, it is found that a decline trend is recorded in the range of 0.10m to 0.50m in Sukna, Sivok and Panighata areas where as a rising trend in water level is noticed around SMC, Matigara, Naxalbari, Kharibari and Phansidewa areas ranging from 0.50m to 1.25 m b.g.l.

The wet seasonal rise up to 4.50m is fully neutralized under the natural processes of groundwater dispersal of rainfall recharge, during the succeeding dry season, so, that the wet seasonal rise equals to the dry seasonal decline, but rise of more than 4.50m results in an annual rise by an amount by which the wet seasonal rise is in excess of 4.50m (Table–5.2). Thus, the water table remains unchanged at the end of a normal rainfall year, but an annual, rise of about 1.75m is recorded at end of a heavy rainfall year. The water table begins to rise from July, both in normal and heavy rainfall season, following the break of the monsoon rains in the middle of June, and the rise continues up to early September in a normal and up to early October in a heavy rainfall year. Further, the water table maxima are attained in both the cases in August, although, in the event of same time lag in any year, the same may be recorded only in September. Simultaneously, water table begins to decline from early October in case of a normal rainfall year or early November in case of a heavy rainfall year and the lowest level is attained in either case in April and it shows a little change until July i.e., when the next cycle of fluctuation commences.

The groundwater recharge does not occur immediately with commencement of the wet season in early June since the portion of rainfall or of rainfall plus irrigation water reaching the water table is dependent upon the balance after its disposal as evapo-transpiration, soil moisture recharge, surface runoff etc. (Tables-5.3 & 5.4). The sufficient recharge to groundwater takes place after July when the soil moisture deficiency is replenished and evaporation losses decreases sufficiently due to the increases of humidity of the surrounding air in rainy season. Thus 'August and September' or sometimes 'October' is the month in which sufficient recharge to groundwater takes place for which the water table fluctuates. In a heavy rainfall year the recharge to groundwater takes place in July as well as in October. On the statistical examination of fluctuations of the water table due to rainfall and irrigation in the study area, Chaturvedi's formula (1947) has been applied to estimate the amount of rainwater reaching the water table.

However, certain dissimilarities in water table fluctuations although of a minor nature, may be noticed in the area with respect to time of water table rise or decline and their magnitudes. These differences mainly arise out of aerial variations in the heavy falls of rain and in water table depth below the ground, influence of the tube well pumping, and the fact that the wells might not have all been measured simultaneously. It may be concluded that, the water table fluctuations in any year in the investigated areas are wholly controlled by variations in local rainfall amounts.

b) Related to Pumping :

The water table fluctuations due to pumping formed a feature commonly observed in the area of investigations which is a very sharp and a very small water table changes, generally controlled by the changing of crop requirements for irrigation water. However, the changes in the pumping intensities are hardly discernable from the well hydrographs and this could be due to the effect of interference amongst the neighbouring tubewells, the effect of time lag in the transmission of the pumping influences to the water table and so on. In fact, these small water table changes are superimposed upon the more well-marked changes due to rainfall variations. On the other hand, as mentioned earlier, the water table registers a decline throughout a low rainfall year–the effect of rainfall recharge being negligible. Since this decline is wholly due to pumping (both dug wells and tubewells), the net effect of the changes in the pumping intensities during the year are to be brought about a uniform decline in the water table, the total annual decline being 0.05m (Table–5.2). The figures for water table changes in a normal or a heavy rainfall year may also be noted from Table–5.2.

The net effect of pumping on the water table during the wet season, in a normal or a heavy rainfall year, is 0.15m and 0.10m obtained by subtracting the amount of seasonal rise in the well areas from the corresponding rise in the areas outside. The average rate of pumping in a year during May-October and November–April is the same in any area since the volume of water withdrawn in each is approximately the same. Hence the amount of decline due to pumping of wells (dug and tubewells) in each of the two periods in a year is almost the same and the total annual decline is twice the value of the wet seasonal decline These are 0.30 m and 0.20 m in a normal and a heavy rainfall year successively.

Further it may be mentioned that water table decline due to pumping in a low rainfall year or a progressive decline during a drought period gets completely wiped off from rainfall recharge in the succeeding heavy rainfall years. Moreover, it has been observed from the previous records that the intensity of pumping in the areas is always within the safe limits. The deep tubewells are used for urban water supply in Siliguri town, in and around Bagdogra, Naxalbari, Kharibari and Phansidewa area. Dug well and shallow tube wells (both pumping and manual) are used for irrigation mainly in the Kharibari and Phansidewa blocks. But the level of utilization of rainwater resource is not significant with respect to its potentialities, hence, the rain water which is available in abundance goes wasted as a rejected recharge.

c) Related to Influent Seepage:

The water table fluctuations by influent seepage from surface water bodies could possibly occur in the area through streams, reservoirs and canals. Influent seepage from rivers and streams like Mahananda, Mechi, Balason, Manjha, Dumri, etc. which are flowing through the study areas are negligible since their water levels remain below the water table of the surrounding area except during the heavy floods. Further, the other sources of influent seepage from surface water bodies like Jhoras, tanks and canals and return flow from applied irrigation is not large enough to significantly influence the groundwater table. This becomes obvious from a comparison of hydrographs of wells situated within and outside the respective areas of influence.

d) Related to Effluent Seepage :

Fluctuations of water table due to effluent seepage into surface water bodies could occur in the case of streams or rivers with their bed level below the water table of the surrounding areas. However, the available stream discharge data is quite insufficient to determine the amount of effluent seepage. A study of the water level depth records of observation wells situated in the vicinity of a stream does not reveal any significant difference with those situated farther away from the streams and rivers. From the water table contour map of the study area (Figs. – 5.5 & 5.6) and their movement of groundwater direction in different tracts indicate that the slope of the water table varies from moderately steep to steep. As a result, the movement of groundwater towards the streams and rivers becomes remarkable and thus the area of investigation takes place the effluent seepage into the distinguished rivers and streams.

e) Related to Evapo-Transpiration :

A climate can not be classified to be dry or moist by knowing the precipitation amount only. It must be known whether the rainfall amount is greater or less than the water need for evaporation and transpiration. The rate of evaporation depends on several factors. It increases with decrease in barometric pressure, increase of air and water temperature, sunshine, wind velocity, dryness of air and purity of water. And the rate of transpiration depends mainly on the species of plants, density of plant growth, meteorological conditions and moisture content of the soil. Hence the cumulative loss by evaporation and transpiration is termed as evapo-transpiration which represent the actual transport of water from the earth back to the atmosphere. These processes may cause water table fluctuations by the discharge of groundwater potential evapo-transpiration is an index of the water that would evaporate and transpire if it were always available from the soil and plants. It does not therefore represent the actual transfer of water to the atmosphere but rather the transfer that would be possible under ideal conditions of soil-moisture and vegetation. In fact, the potential evapo-transpiration becomes the actual evapo-transpiration when the water needs the plants are fully met with from precipitation all the year round. But the amount of rainfall through a year rarely coincides with the changing water needs and hence the actual evapo-transpiration is generally much lower than the corresponding potential evapo-transpiration. From the numerous investigations carried out in this field all over India, the evapo-transpiration rates have been found to mainly depend upon the following four factors–climate, soil moisture supply, plant cover and land use pattern.

The amount of potential evapo-transpiration through a year follows a set pattern over the study area and there is a close parallelism between rainfall, temperature and potential evapo-transpiration although they are not linked to a common reason but are evidently the result of different causes. From the analysis of Tables-5.3 and 5.4, Fig.–5.8 and temperature Table–1.1, it is observed that the potential evapo-transpiration rates increase with an increase in temperature and a decrease in relative humidity. It is further observed that the rate of increase is steady from January to May, with increasing temperatures and the aridity followed by a rapid decline from June onwards with the onset of the usual precipitation. The minimum is ultimately reached in the month of August, which also records the heaviest rainfall as well as the relative humidity. A very gradual rise in the rates is to be noted from September with a slight increase in air temperatures following a decline in rainfall and cloudiness. The rise does not continue beyond October with the approach of the cold season.

The potential evapo-transpiration is distinguished from the actual evapo-transpiration depending upon the amount of water actually available for plant growth and therefore it will be a function of rainfall provided there is no soil moisture recharge by capillarity from the water table and flat artificial irrigation is not prevalent (Tables –5.3 & 5.4). Moreover, the actual evapo-transpiration in any month will be less than or equal to the corresponding potential evapo-transpiration according to an existence or otherwise of a water deficiency in that month. Thus the actual equals to the potential only in the wet season (June, July, August and September) and somehow extends to October, when there is no water crisis in the area. It may be pointed out that there is no general uniformity in the nature of the plant cover over the study area. Furthermore, maximum land area are cropped and that too mainly under the short-rooted plants like–wheat, paddy, sugarcane, tea plant and bamboo bushes and partly is covered by forest trees–Sal, Gamari, Simul-Siris, Khair-sissu etc. located at Sukna, Panighata, Dudhia, Sevok and Ambari area. From investigation of the different species of plant, it is to be concluded that the height of the capillary fringe above the water table is about 2 m whereas the average depth of water table below the ground is about 4 m to 5m. Hence, the prospects of any groundwater discharge by evapo-transpiration would be rather remote through these plants.

There is a possibility to become evapo-transpiration through the long rooted forest plants but analytically it is not significant because Burr and others (1904) reported that groundwater does not rise to the surface by capillarity if the water table is at a depth of 2.5 m or more in a fine soil or 1 m to 1.5 m in coarse sand or gravel. According to the theory of Burr et. al no significant groundwater discharge through the evapo-transpiration is occurred in the area of investigations. Moreover, an incomplete and irregular data is found in different Tea Gardens. Rain gauge stations as well as the terai meteorological sub-station at Gangaram Tea Estate, an indirect estimation of evaporation and transpiration losses is done by estimating the potential evapo-transpiration of water need of a region according to Thornthwaite (1948). It is the amount of water that would transpire and evaporate if it were available. Potential evapo-transpiration and rainfall in different months in the Terai region of a normal rainfall year is shown in Table–5.5.

Table-5.5 : Potential evapo-transpiration and rainfall in the study area (1998).

Items	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean potential evapo-transpiration in mm.	7.25	110.5	140.35	166.70	195.25	150.05	135.35	105.45	112.25	120.01	115.65	78.15	1479.21
Normal annual rainfall in mm.	25.70	3.70	27.70	58.30	192.60	524.90	1226.70	699.60	570.30	6.30	0.00	1.00	3336.80

It has already been mentioned that the rainfall, before reaching to water table, replenishes the soil moisture deficiency and losses due to evapo-transpiration. As for instance, the rainfall amount in June, in a normal rainfall year in the study area is 524.90 mm which is 374.85 mm in excess of the mean potential evapo-transpiration and this exceeds 374.85 mm of water partially replenishing the prevailing soil moisture deficiency.

It is worthwhile to describe here a few lines about the climatic type of the study area of investigation according to rational classification of Thornthwaite. Subrahmaniyam (1956) classified the climatic types of 250 stations of India and used the moisture-index for classification. Thornthwaite defined –

$$I_m = \frac{100\,S - 60\,d}{n}$$

where, I_m = moisture index, s = annual water surplus, d = annual water deficiency, and n = annual water need or potential evapo-transpiration all expressed in same unit.

Therefore I_m is non-dimensional and positive and negative values of I_m signify the moist and dry climates respectively. The following values are calculated by Subrahmaniyam for the terai area of Darjiling district :

$s = 374.85$ mm, $d = 0$ mm and $n = 1497.21$ mm

By putting these values in the equation, which gives the value of I_m to be +25.04 and indicates broadly that the climate of the area of investigation of Darjiling district is wet. On the basis of moisture index and climatic types, Terai area of Darjiling district has been found to be 'tropical rainy climate'.

CONCLUSION

The experimental analysis of this chapter indicates that the water table is an indicator of the hydraulic conditions prevailing in the zone of saturation. The form of water table is largely controlled by topography. The water table fluctuations in the study area occur mainly from variations in local rainfall, tubewell and dugwell pumping during a year, the fluctuations due to pumping being superimposed upon the more prominent fluctuations due to rainfall, but unfortunately this region is very much neglected due to being less developed area through irrigation. The water table is also slightly being affected by evapo-transpiration and effluent seepage into surface water bodies, but no effect is obtained by means of influent seepage from the surface water. Generally, the water in the piedmont plain is deeper than that of alluvial plain in the area. Seasonal fluctuation of water table in piedmont plain ranges from 4m to over 6m, whereas it is restricted within 2.5m only in the alluvial plain. The long term trend of water levels reveal that the declining and rising trend is restricted within 1m to 1.5m only during the last 10years(1989-1998) and hence it can be concluded that no caution is needed to be exercised for the development of the groundwater in the study area.

The water table fluctuation is largely dependent upon the recharge and discharge of groundwater, safe yield of the groundwater reservoir etc. which have been discussed elaborately in the following Chapter.